AUGUST 1961

NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

RADIATION JOINS THE PROCESS LINE

NEUTRONS GAGE FOUNDRY-SAND MOISTURE

PAGE 45

IRRADIATED POLYETHYLENE COMES OF AGE

PAGE 54

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X-RAYING LARGEST STAINLESS STEEL "HOT" PUMP CASTING

Above, technicians mark segment of casting for one of many hundreds of X-ray pictures employing a 24,000,000 volt Betatron at the Bonney Floyd Foundry. *Below*, X-ray picture is carefully inspected for flaws.

Shown here is the largest single-piece stainless steel pump casting built today. The X-ray procedure is just one of the many inspections necessary to assure the high quality in Worthington nuclear pumps. Special designs were necessary to allow a single casting to be made for this size pump.

A more complete discussion of special equipment criteria and manufacturing techniques for nuclear requirements is available in a Worthington pamphlet, "Manufacturing For a Nuclear Power Plant." Ask for RP-1092.

To provide the special attention required to engineer and manufacture nuclear products, Worthington has an Advanced Products Division which specializes in pumps and other equipment for nuclear plants. For further information, write Worthington Corporation, Nuclear Department 106-7, Harrison, New Jersey.

WORTHINGTON

PRODUCTS THAT WORK FOR YOUR PROFIT

From scaffolding over core, B&W technician checks fuel element arrangement prior to criticality tests.

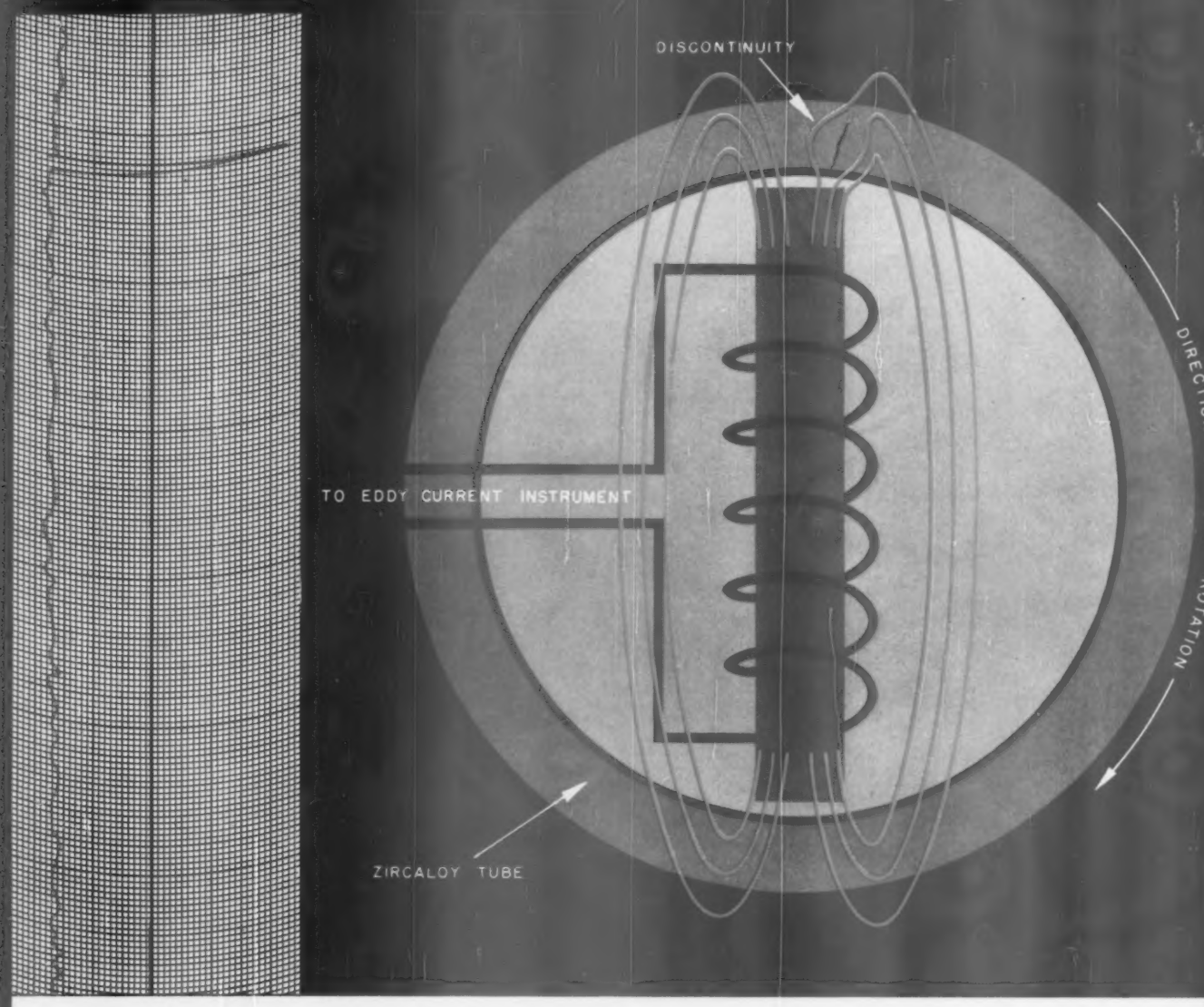
Con Edison core goes critical at B&W laboratories

On June 29, criticality was achieved in the thoria-urania fueled reactor core that will power Consolidated Edison's 275,000 kw Indian Point Station, now nearing completion.

Indian Point will be the nation's largest power plant employing nuclear power. Steam produced by the reactor will pass through oil-fired super-heaters, permitting turbine operation at 1000 F.

The full-core criticality tests, performed at B&W's Lynchburg, Virginia, nuclear facilities, are intended to confirm the nuclear design of the core. Further, important loading procedures to be used when the core is installed at Indian Point later this year will be determined. Pioneered by B&W, the unique thoria-urania fuel—with a conversion ratio providing extended core life—contains 93% thorium oxide. The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, New York.

Babcock & Wilcox

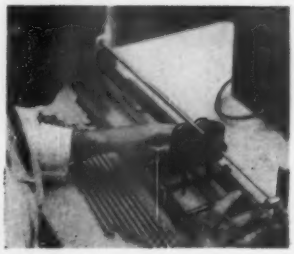


EDDY CURRENT PROBES INSIDE STORY ON PATHFINDER FUEL ELEMENT TUBING

Revealing the inside story on 60,000 tubes for the Pathfinder Reactor assured freedom from cracks greater than 5% of wall thickness on inside diameter.

This schematic end view of a rotating tube and the inserted probe illustrates the eddy current paths. When an inside diameter surface or subsurface discontinuity passes over the probe, changes occur in the electrical value of the coil (impedance). A corresponding change in voltage and current flow within the coil is converted and fed to the chart recorder (left). Interchangeable probes provide 100% non-destructive testing of both zircaloy tubing and end cap welds.

This is an example of quality control applied to Pathfinder fuel elements being manufactured by Metals & Controls Inc., a corporate division of Texas Instruments Incorporated for the Allis Chalmers Manufacturing Company. Similar quality control methods and complete laboratory facilities of our nuclear products group are ready to work for you to insure complete integrity of components for your nuclear projects. Our colorful booklet, "Fuels of the Future," is available on request from department NU-8.



This semi-automatic, non-destructive test apparatus, devised by T.I.'s scientists, rotates tubing while electronic probe is inserted.

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NUCLEONICS

APPLIED RADIATION • ATOMIC POWER • NUCLEAR ENGINEERING

AUGUST 1961 • VOLUME 19 NUMBER 8

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...about NUCLEONICS

Nuclear Scholarship

"I believe deeply in the importance of basic research . . . for its intellectual value."

—Leland J. Haworth

A real danger to America as a civilization is that efforts for the short-term goal of practical results will drown the long-term goal of making better men. Concern for science may overwhelm our concern for scientists. It is too easy to forget that impractical things like imaginary numbers, developed just for fun, precede practical things like intercontinental telephones and television.

We at NUCLEONICS are devoted to academic aspects of nuclear science as is AEC Commissioner Haworth. Two kinds of scholarship must always be important: research, which unravels the secrets of nature, and study to make what we discover easier to understand. We can only develop properly if we find fun in ingenuity and stimulation in intellectual challenge.

PEGGY JACKSON of NUCLEONICS news staff interviews I. H. Usmani, chairman of Pakistan atomic-energy commission, and S. Baron of Burns and Roe, occasional contributor to NUCLEONICS pages

Since editorial pages are hard to pay for and difficult to produce, we have little space for truly tutorial articles. Our field is new developments, and we leave largely to teachers and text books the kind of study that reviews, revises and correlates.

Nevertheless in three ways we try to make our contribution to scholarship: Each item and article is intended to include introductory and background material. For our own staff a film program serves as a nuclear-technology course.

Finally, in response to questions from scholars of all ages, we write letters and mail literature. In our photograph you will see the NUCLEONICS staffer who carries on the last two of our "academic" programs.

Will You Help Us?

We of the NUCLEONICS staff are always happy to answer student letters that request information about nucleonics. Usually we have on hand a file of literature. Sometimes, however, the file runs out, if not altogether, then in some aspects. We may have lots of folders on how the atom produces energy and none to answer a question about how radiotracers are used in medical diagnosis.

Do you have literature you can send us for educational purposes? If you have, we will be happy to have some copies to send to students who need them. Do you have literature that you would be happy to send yourself to students who ask for it? If you do, we will be glad to be made aware of it. Send your literature—or your list of titles—to our "Student Service Department."

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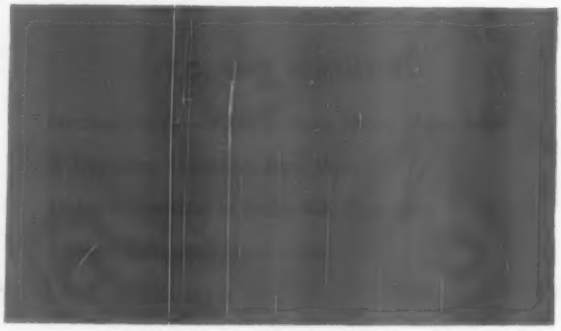

MARTIN NUCLEAR ROCKET PROGRAM

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NUCLEAR ROCKET SAFETY ANALYSIS
RADIATION EFFECTS ON ROCKET SYSTEM
FUEL ELEMENT DEVELOPMENT
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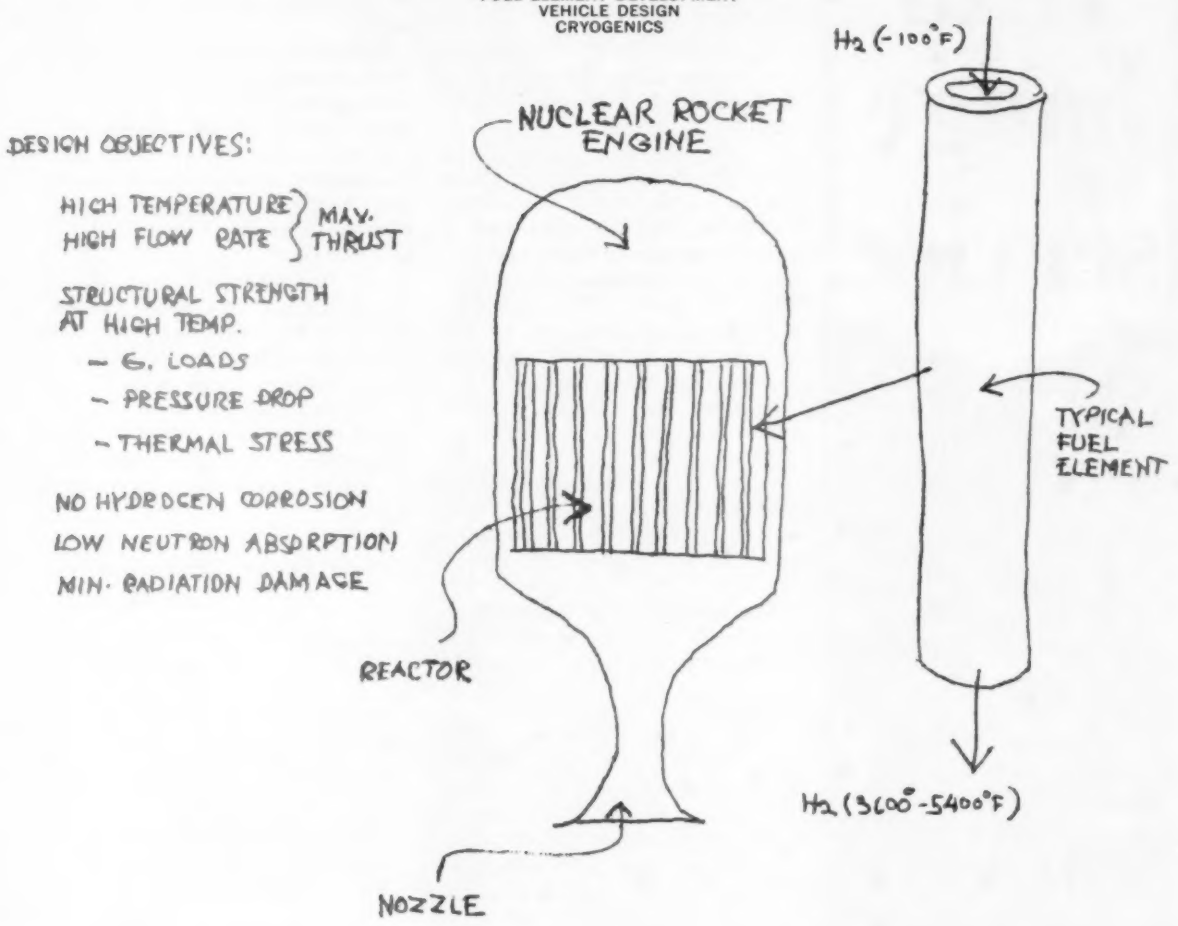

THE PROBLEM OF FUEL ELEMENT DEVELOPMENT FOR NUCLEAR ROCKETS

Nuclear propulsion offers advantages for extended space exploration simply because nuclear energy provides more power per pound than any other power source known. Because fuel element temperatures for rocket reactors may range as high as 5400°F (higher than the boiling point of steel), the limitations of existing materials make the achievement of good fuel element characteristics extremely difficult. Drawing upon its existing materials research and development capabilities and background of producing fuel elements for a variety of reactors, The Martin Company has sponsored an independent program for a number of years directed toward the fabrication of suitable nuclear fuel elements for rocket reactors. This is part of a broad Martin program designed to help meet our national goals of testing the first nuclear flight system by 1966-67.

Test of a fuel element in a plazma jet chamber being conducted at Martin's Nuclear Division.

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NUCLEAR REACTIONS

Carbon Steel in Halden Reactor

DEAR SIR:

In the March issue of NUCLEONICS there is a very interesting note by H. R. Kosmata titled, "NRP Uses Carbon Steel."

In this connection, it might be of interest to the readers of NUCLEONICS to know that the Halden Boiling Water Reactor has used mild carbon steel for out-of-pile sections of the primary loop since it was commissioned in June 1959. From that month to October 1960 a low-power, low-temperature research program was carried out, and from October 1960 through April 1961 the reactor has been operated at 150°C with a maximum power level of 5 Mw.

The fuel elements during these low-power runs were natural uranium metal rods canned in 2S aluminum. It might also be of interest to note that the aluminum has behaved excellently at 150°C.

The temperature and power level will now be increased to 230°C and 20 Mw respectively with a new fuel charge of sintered UO_2 canned in zircaloy-2.

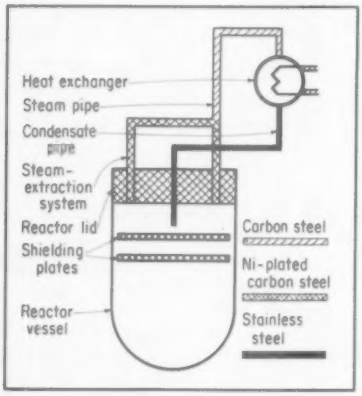
The material selections for the primary loop of the HBWR are shown schematically on the enclosed sketch. The steam pipe leading from the steam-extraction system to the heat exchanger is fabricated from mild-carbon-steel tubing. The same type of material is also used in the steam-extraction system, the reactor lid, and the in-pile shielding plates. However, these latter components have been nickel plated by an electrodeless method. The condensate pipe from the heat exchanger to the reactor is of austenitic stainless steel.

During the 150°C operating period, which lasted seven months, the heavy water conductivity has been maintained between 0.6 and 1.0 μmho/cm.

In spite of the installed unit for recombination of radiolytically decomposed heavy water, the oxygen content of the steam has been high, around 1%. Inspection of the steam pipe carried out recently showed no signs of undue corrosion. As a matter of fact the corrosion was found to be less pronounced than expected; the surface was covered with a dark-brown oxide layer.

This result has been so encouraging that another primary steam pipe from the reactor to a new heat exchanger will also be fabricated from mild carbon steel.

—STEINAR AAS
Senior Metallurgist
Institutt for Atomenergi
Kjeller, Norway



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Bibliography for Lapsley Article

DEAR SIR:

The omission of the bibliography from the article, "Electrostatic Precipitator Detects Fuel Failures," by A. C. Lapsley (NUCLEONICS, May 1961) has unfortunately given a somewhat provincial aspect to the article. We would be very appreciative if you would publish the following references.

W. R. Krita. An automatic gas chromatograph for monitoring of reactor fuel failures Part I; Design, DP-356 (April 1959)

R. Livingston, H. A. Levy. Monitor for fission gases, U. S. Patent No. 2,576,616 (Nov 27, 1951)

E. Long, J. M. Laithwaite, K. W. Cunningham, *Brit. Nuclear Energy Conf.* **2**, 197 (1957)

P. R. Tunnicliffe, A. C. Whittier. Detection of gaseous fission products in water—a method of monitoring fuel sheathing failures. RDP-51 (April 16, 1953)

K. Kandiah, *Proc. Inst. Elec. Engrs.* **101**, Part II, 239 (1954)

M. H. Goosey, NUCLEONICS **17**, No. 9, 104 (1959)

—J. W. HILL

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Aiken, S. C.

Errors in Drag Coefficients

A. N. de Stordeur of BelgoNucleaire S.A., Brussels, Belgium has pointed out to us that several errors were published in his article, "Drag Coefficients for Fuel-Element Spacers," in the June 1961 issue of NUCLEONICS. The correct versions are:

	Should read
p. 76, col. 3, line 17	10^{-6} ft²/sec.
line 23	associated with peripheral pins = 42 (40
line 39	-tral flow cell without wires = $\frac{4A_c}{\pi d}$ =
p. 78, col. 2, line 3	n_1Q_w or $Q_T = (n_2 + n_1K_1)Q_c$ = 123.226
line 5	n_1A_w' which yields $A_T = (n_2 + n_1K_2)$
line 18	$Re_R = \frac{De_cQ_c}{\nu A_c'}$
line 30	$S = \pi(d + d_s)d_s \times \frac{L}{h}$
p. 78, col. 3, line 11	$Re_T = \frac{DeQT}{\nu A_T}$
line 13	$10^{-5}\frac{\Delta P_T}{Q_T^2}$ and $Re_T = 1.538 \times 10^5 Q_T$
line 17	$\frac{d(\Delta P_T)}{\Delta P_T} = \frac{d(\Delta P_R)}{\Delta P_T} + \frac{d(\Delta P_s)}{\Delta P_T}$
line 21	$\frac{d(\Delta P_T)}{\Delta P_T} = 0.4\frac{\Delta P_s}{\Delta P_T} = 0.4\frac{\Delta P_s}{\Delta P_R + \Delta P_s}$

(Continued on page 86)

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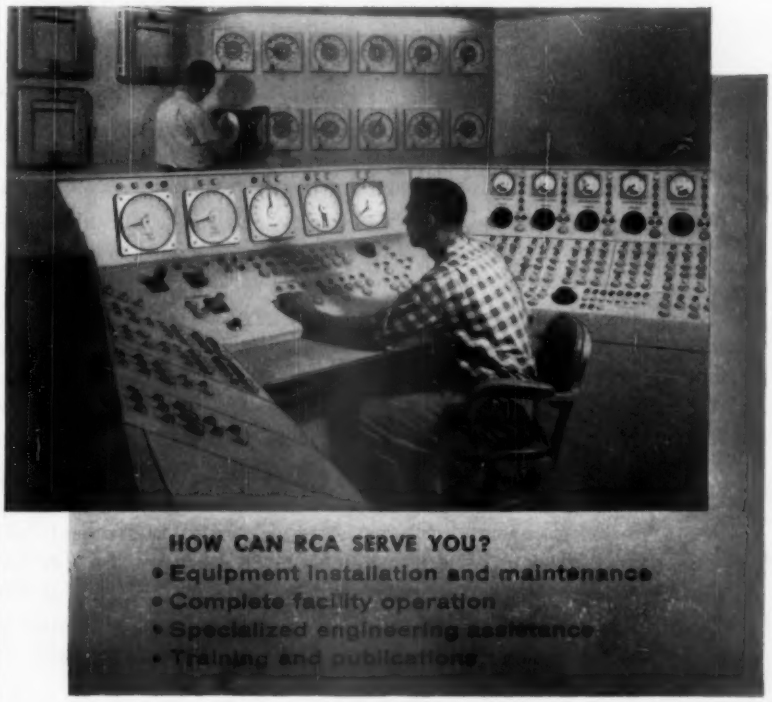

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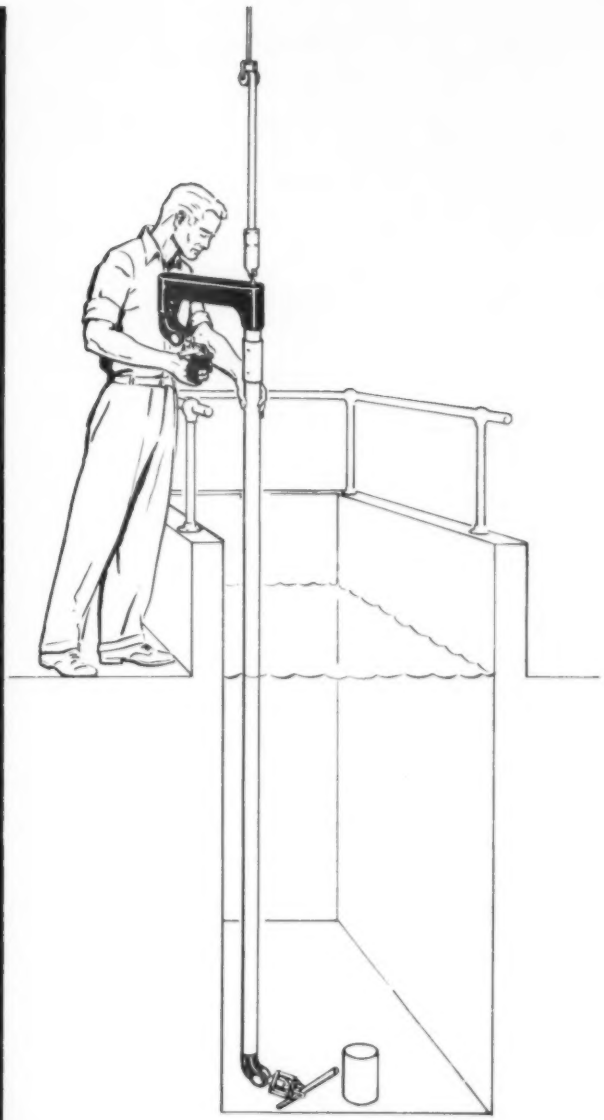
Central Research Laboratories' model B canal manipulator



If your operation has required grappling and fishing at the bottom of a canal or pool, Central Research Laboratories' Model B Canal Manipulator may be the new tool for you. Master-Slave Manipulator type ambidextrous handle, wrist joints, and tongs are coupled by alloy tapes passing through a cross-over housing and long vertical tube. This makes possible dexterous underwater manipulation. All submerged components are stainless steel for maximum corrosion resistance.

Wrist Joint and Tong Motions

The wide range of wrist-joint and tong motions insures deft and adroit handling of large and small objects. Squeeze motion is 3½ inches with an elevation rotation of 168° going from 38° back of vertical to 40° above horizontal. Twist rotation is 360° minimum at ends of elevation range, 720° when the tong is pointed 45° downward.

Azimuth rotation and X, Y, and Z translations are provided by gross movement of the vertical support tube. A constant force spring suspension supports the manipulator in the canal or pool.

For further versatility, the Model B Canal Manipulator may be equipped with standard or special purpose interchangeable tongs of either the RCD-447-100 or SRL-IIA type. Vertical tubes of desired length are available to meet most requirements.

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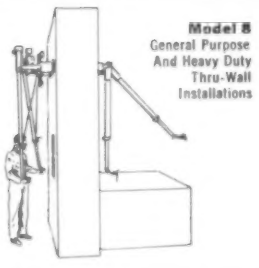

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Installations

Model 7
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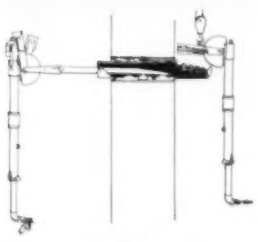

Model A Sealed

For further information on Central Research manipulators, accessories, or hot cell design problems, write:

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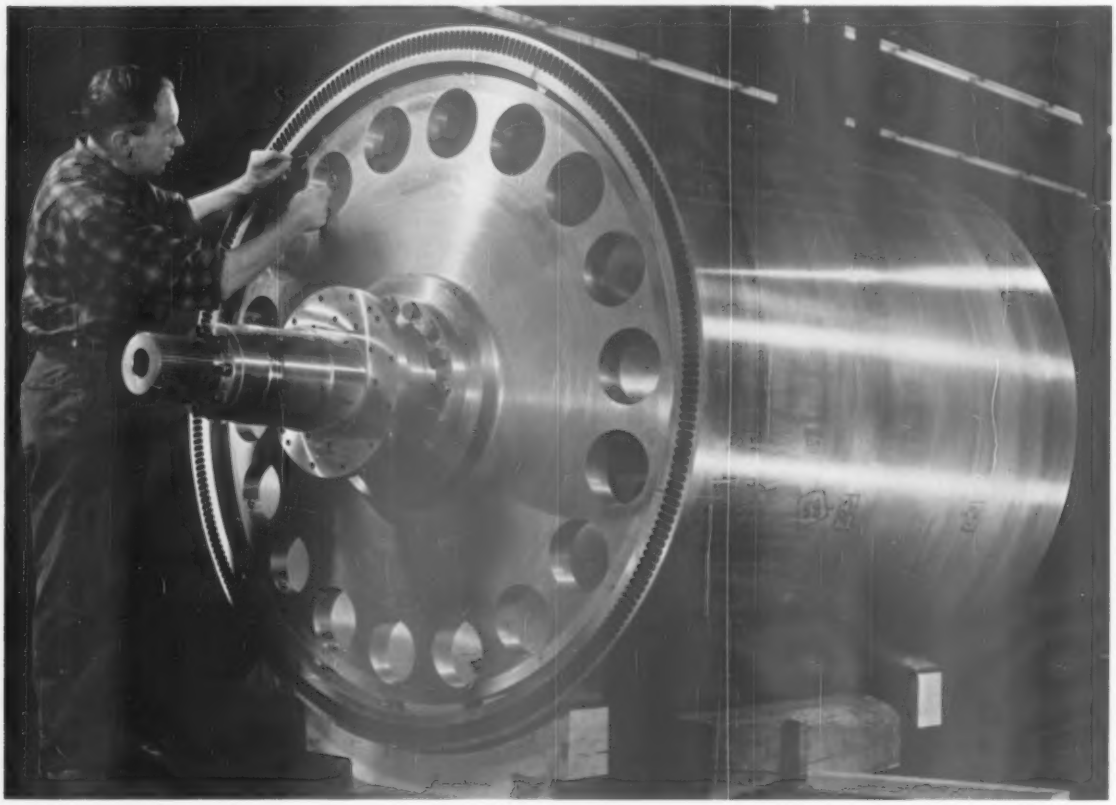
Three-ring rotor, showing rectangular holes through ring wall, with end plates and tubular spindle assembled into a unit ready to ship.



How to bring a missile back through temperatures to 8,500°F

You can broil a steak at 350°F. Pure iron melts at 2795°F. Most meteorites burn up when they enter the earth's dense atmosphere. Today, man is firing missiles to meteoric altitudes—but the problems of tolerating the extreme temperatures of re-entry have been the greatest challenge to his ingenuity.

One of the major obstacles to simulating re-entry conditions was how to produce for realistic time durations pure air in large volumes at meaningful temperatures, pressures and velocities. This problem is being solved with the *Wave Superheater*—an innovation in hypersonic wind tunnels. Temperatures to 8500°F, pressures to 200 atmospheres and velocities up to Mach 15 can be attained with this facility. Cornell Aeronautical Laboratory has devised this equipment to test full-scale missile components in the laboratory.

The wave superheater is essentially a blow down system using a rotor with 288 tubes (passages) drilled into its periphery. The shock tubes are charged with air; then a driver gas (helium) at a pressure of 1500 psi is released through one end of each tube, successively superheating by shock waves the air which is then collected and expanded into the wind tunnel. The rotor operates at a maximum temperature of 800°F; each tube is momentarily cooled as it rotates, to be ready for the next charge.

Rotor Ring Forgings. The heart of the superheater is the rotor made from three USS Stainless W forgings. The rough-machined rings are each 63″ OD, 54″ ID, 23½″ long and weigh 6,000 pounds each. USS Stainless W was chosen for this demanding application because of its precipitation hardening characteristics, and its ability to retain the required high strength at the operating temperature.

The three rings were obtained from a 59″ diameter ingot, which was cogged, sheared, upset-forged, punched and finally mandrel-forged under our 10,000-ton press. After rough machining and completing the inspections called for, the rings were shipped to 20th Century Machine Tool Company, Utica, Michigan, who drilled and broached the holes seen in the assembled view of the three-ring rotor. With an assist by Hoover Tool & Die Company, Warren, Michigan, the final machining and assembly was completed in 10 months.

No matter what kind or size of USS Quality Forgings you need, you get the advantages of the finest steel, the most modern equipment and the most skilled forging men in the world. Address inquiries to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. A copy of our booklet "USS Nuclear Forgings" may be secured by writing to the same address. USS is a registered trademark.

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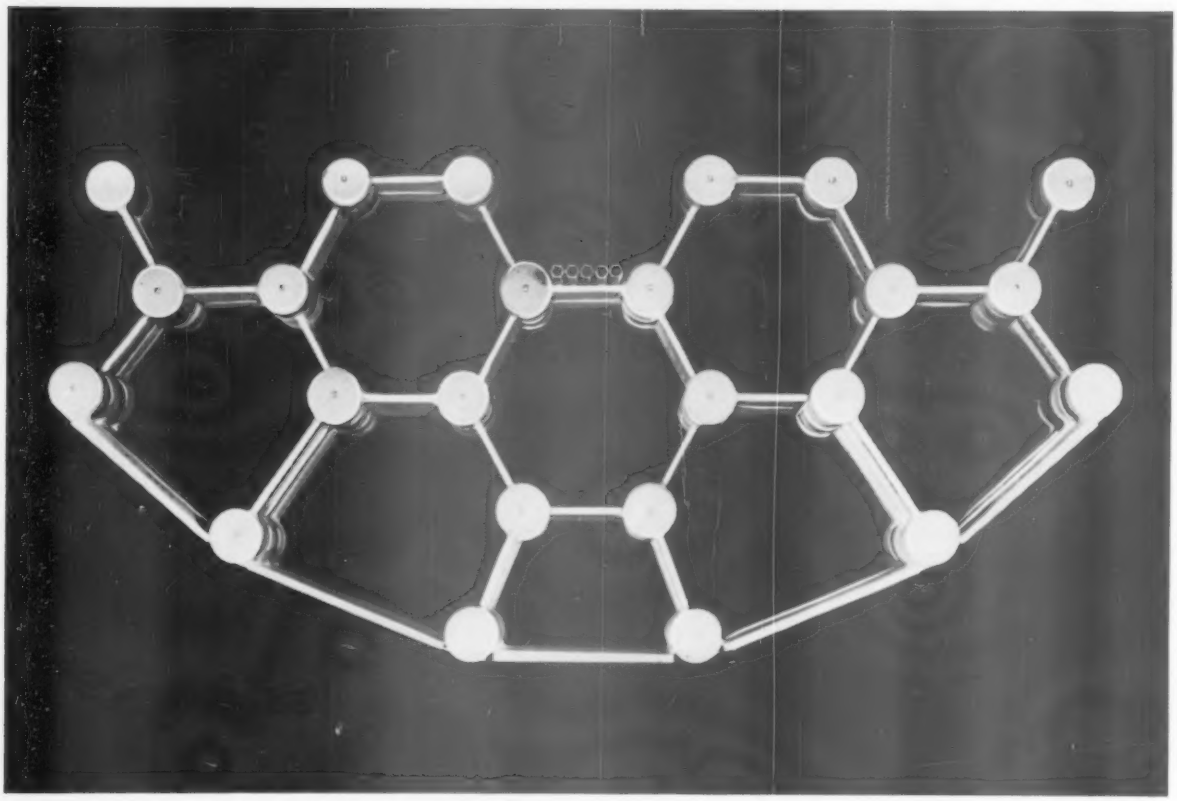
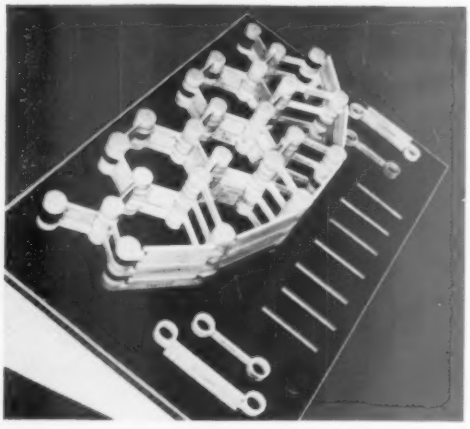


Building a Beehive of Nuclear Activity . . .

Curtiss-Wright BeO Components Shape and Strengthen Core of Tory II-A1 Nuclear Ramjet Reactor



An assembly of beryllium oxide ceramic links is shown above in the actual configuration of the Tory II-A1 experimental reactor. Individual links which make up the honeycomb are shown in the foreground. The fuel elements, containing BeO and Uranium, are hexagonal ceramic tubes nested together and held in position by the structural links.

In the core of the Tory II-A1 nuclear ramjet reactor, complex beryllium oxide ceramic links, fabricated in quantity by the Research Division of Curtiss-Wright Corporation, help provide structural shape and strength at the stringent thermal conditions present within the structure of the core.

Curtiss-Wright manufactured beryllium oxide shapes are components of the reactor and act as in-core moderator in the power tests being conducted with the Tory II-A1. The reactor is being developed as part of the AEC's Pluto Program to demonstrate the feasibility of using nuclear energy as a heat source for ramjet propulsion. The Research Division has also developed processes for fabricating ceramic fuel elements for this type of reactor.

One of the nation's leading producers of high purity beryllium oxide components — for reflectors, moderators, fuel elements and other applications — the Research Division has facilities for fabricating massive blocks, cylinders, thin wall tubes and other complex shapes. Based on experience — consult Curtiss-Wright on your beryllium oxide requirements.

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custom instrumentation

controls one-megawatt "swimming pool" reactor

The Honeywell control system for the University of Virginia's "swimming pool" reactor combines wide operating flexibility with safe, sure reactor control. The system is custom designed to handle all operating functions of the reactor, and to provide thorough grounding for student engineers in basic nuclear instrumentation.

Rated at one-megawatt, the reactor ranks as one of the most powerful university nuclear facilities in the nation. The reactor core has twenty fuel elements, each with twelve fuel plates made of uranium aluminum alloy. Total fuel charge amounts to about three kilograms uranium, enriched in U-235 isotope.

The reactor is currently used to train graduate students in practical nuclear engineering. Student engineers "learn by doing" under the watchful eye of qualified instructors and skilled technicians. Equally important, the reactor serves as a research facility for the Departments of Biology, Chemistry and Physics, and Schools of Engineering and Medicine.

This custom-built control system is merely one example of Honeywell's experience in nuclear instrumentation. From the design and manufacture of components . . . to building complete reactor control systems . . . to installation, startup, and service, Honeywell can help you achieve efficient, economical and reliable control of your nuclear project. Your nearby Honeywell field engineer will be glad to discuss your nuclear instrumentation requirements.

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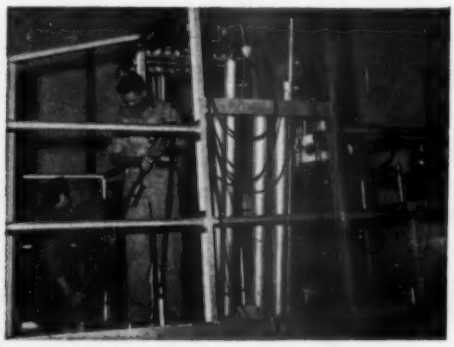
The Honeywell control console is located on a mobile bridge which spans the width of the pool. The bridge can be moved to position the core at any point along the length of the pool. Console instrumentation includes Honeywell ElectroniK 15 recorders (log count rate, linear power, log N), nuclear amplifiers, power set control unit, rod position indicators, and reactor scram annunciator.



The center of the control bridge functions as the nuclear work area. Supported from this point are the core, the control rod drive mechanisms, safety rod magnet assemblies, and neutron counters. Instructors and skilled technicians supervise and assist graduate students in setting up and performing reactor experiments. In this way, student engineers learn practical nuclear physics and reactor technology.

Nuclear-Chicago's new family of liquid scintillation counters—

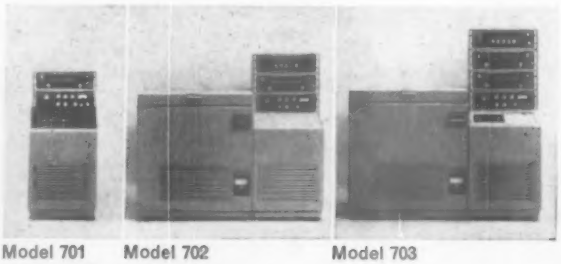
Just months old and already meeting the critical demands of exacting research

Although introduced and well received just last April, Nuclear-Chicago's new family of liquid scintillation counters is already hard at work. At varying levels of work load and within widely differing budgets, these three systems are setting new standards of precision, sensitivity and convenience for demanding scientists.

Research programs expand and equipment needs are upgraded. These new counting systems—compatible with your present, standard scaling instruments—easily accommodate to such growth.

Model 701 is a modestly priced, basic system for manual, room-temperature counting of limited numbers of samples. Uniquely sensitive detector assembly and advanced, transistorized circuitry provide high counting efficiency for carbon-14, tritium, and other soft-beta emitting isotopes. **Model 702** adds a precision-controlled low-temperature chamber for increased tritium-counting efficiency. The third member of the family, **Model 703,** provides fully automatic sample handling and varied options of readout.

Field conversion to upgrade Models 701 and 702 as work load and budget permit requires only the addition, first, of the custom-built, compact cooling chamber, and then, of the automatic sample changer mechanism.



Model 701 **Model 702** **Model 703**

Model 701—manual operation, shown with 8250 scaler

Model 702—manual, temperature-controlled operation, shown with 8250 scaler and 8600 timer

Model 703—automatic, temperature-controlled operation, shown with two 8250 scalers, 8600 timer and 8401 digital recorder

Please request literature on these integrated systems.

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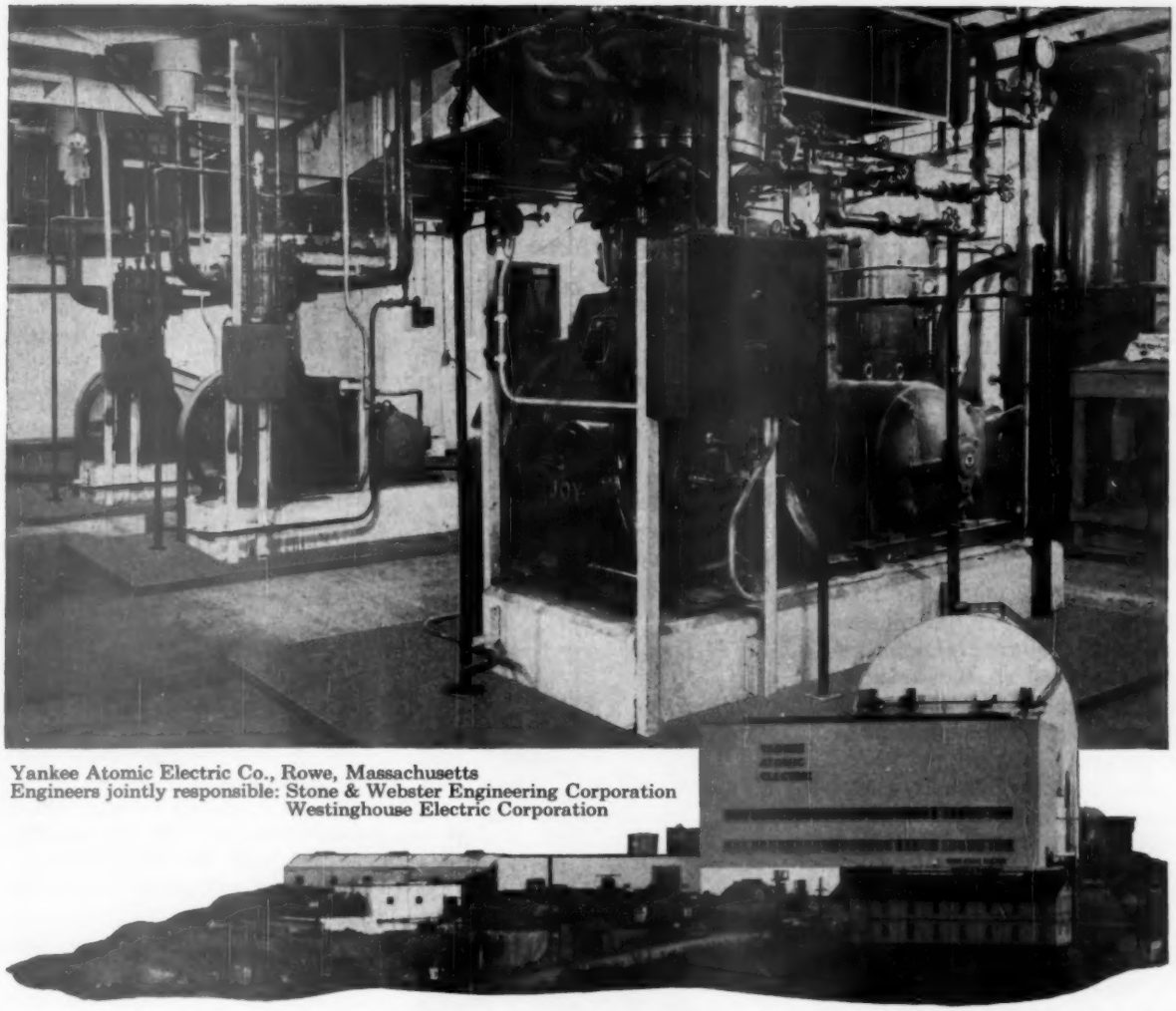

Yankee Atomic Electric Co., Rowe, Massachusetts
Engineers jointly responsible: Stone & Webster Engineering Corporation
Westinghouse Electric Corporation

Yankee Atomic Electric chooses JOY Compressors for New England's first Nuclear Power Plant

Compressed air requirements at the Yankee Atomic Electric plant are not large but vitally important. Reliability of all machinery is a must, once the reactor goes critical. Two Joy WGO-9 vertical compressors supply oil-free air for instruments and controls. Each machine produces 172 cfm at 100 psi and is V-belt driven by a 25 horsepower motor. Carbon graphite piston rings completely eliminate lubricating oil in the cylinders. The compact vertical design requires less than seven square feet of floor space for each installation.

General service air is supplied by a 100 hp Joy WG-9H compressor producing 769 cfm at 100 psi. This machine has the same space-saving vertical design in sizes up to 150 hp.

Joy compressors are chosen for many of the country's finest installations . . . there is a size and type for you, reciprocating, centrifugal or axial. For information, write for bulletin 1685-92

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Rockwell-Edward Nuclear

Shippingport, Pennsylvania, 1961: After more than three years of operation, it is possible to report in depth on the manufacture and performance of Rockwell-Edward high-pressure steel valves built for Shippingport, pioneer nuclear power generating station. This report deals with two areas:

1. *How Rockwell-Edward quality control met rigid Shippingport requirements.*
2. *How relatively standard design Edward valves have performed in Shippingport nuclear service since startup in 1957.*

Quality Control

Quality control of the highest order in building steel nuclear valves for the Duquesne Light Company-operated Shippingport Station brought the valve maker's art to new heights. These valves, for the primary coolant system in the first full-scale nuclear power generating station, were furnished by Edward Valves in 1-inch to 18-inch sizes. Since no valves had ever been called upon to perform in such service before and since slightest valve failure could have consequences far more serious than any possible before, Edward was called upon to apply every conceivable technique of quality control known.

From the very beginning, physical and chemical analysis of all component materials was made on every lot and every heat. Statistical lot testing was not adequate.

Testing and Measurement

Normal valve making requires only that certain diameters and angles be watched to critical tolerances. But for the Shippingport valves, every dimension that could be measured was measured and checked to tolerances of thousandths of an inch. All forged steel valve bodies were ultrasonically tested to pick out body flaws that could lead to leaks or stress concentrations. Ultrasonic testing is not ordinarily warranted for valves as small as 1-inch size. After Stellite inlays were laid and machined for seating surfaces, dye penetrants were used to detect porosity, surface flaws, holes and crevices.

All internal surfaces were inspected with a Boroscope. Roughness was held to 30 microinches.

Precision and Cleanliness

Though lapping is usually reserved for valves destined for gas service, the Shippingport valve seats were hand lapped to a maximum roughness of 16 to 30 microinches, rms. All internal surfaces exposed to fluid were polished to 125 microinches, rms. Such fine internal finishing is very difficult on small valves, but had to be done. All internal surfaces were inspected with Boroscopes.

All cleaning and degreasing as well as final assembly were done in the "clean room". All personnel wore lint-free coveralls. No smoking was permitted.

Final Tests

Two-hour hydrostatic tests, back seat tests, and packing tests were done in the "clean room," also. After tests, the completed valves were again oven dried in nitrogen and inspected with a Boroscope for cleanliness, porosity and surface finish. These inspections were made by Edward and representatives of Westinghouse Electric Corp. and the United States Navy. Valves were sealed in polyethylene bags and then removed from the "clean room" for packing according to military standards.

Experience with rigid quality control conditions such as these is hardly routine. But it illustrates what a valve maker can do with his standard line.

Performance Record

Not a single complaint has been received on any of the more than 100 Edward one-inch and two-inch forged steel globe stop valves used in the high-pressure primary reactor system, or on the four 18-inch tilting disk check valves used in the primary coolant pump discharge lines.

A few of the globe stop valves have required routine seat maintenance, but no more than would be expected. Leakage through the packing of the globe stop valves has been consistently within expected limits . . . that

Valve Report:

is, so minute as to be of no consequence. In fact, although many of the Edward globe stop valves were furnished with weldable caps as a precaution against packing leakage, the caps have been welded into place only on those valves in relatively inaccessible areas near the reactor.

Forged steel valves for Shippingport—and for the Westinghouse Belgian reactor and other nuclear projects—were individually sealed in plastic bags.

In furnishing high-pressure steel valves for virtually every U.S. nuclear power plant built to date, Edward has demonstrated that excellence of design and manufacture is *the* important ingredient in nuclear power valving, just as it has been in conventional power valving for more than fifty years. They have proved that there *are* important differences in various steel valve lines . . . and that Edward customers get the benefit of these differences.

Edward builds a complete line of forged and cast steel valves from ¼" to 24" for power, industrial, marine, and petroleum services. For more information, contact your Edward Representative, or write Edward Valves, Inc., 1290 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

This valve is typical of smaller capped forged steel stop valves furnished for Shippingport. Cap has been screwed into position on bonnet but has not been seal-welded.

Big Cast Steel Valves, Too

The development of suitable check valves for pump discharge service in primary coolant loops of large pressurized water reactors has been substantially advanced by exhaustive flow testing begun in the Edward research laboratories in the 1940's. Equipped with a flow test loop circulating up to 2,000,000 lb/hr of water and capable of flow reversal in a fraction of a second, Edward research engineers have been able to simulate actual service conditions and develop check valve designs with superior opening and flowing characteristics together with the best possible non-slam features upon flow reversal. Full size prototypes of Shippingport, N. S. Savannah, Enrico Fermi, and Indian Point primary loop check valves were tested with this equipment.

6104

Large 18-inch cast steel stainless steel check valves for Shippingport (left) received same meticulous attention as small forged valves . . . and have functioned with equal dependability since going into service in late 1957.

Other large Rockwell-Edward stainless steel valves were built for primary coolant systems of Babcock & Wilcox N.S. Savannah (center) and Indian Point (right) reactors.

EDWARD STEEL VALVES
another fine product by
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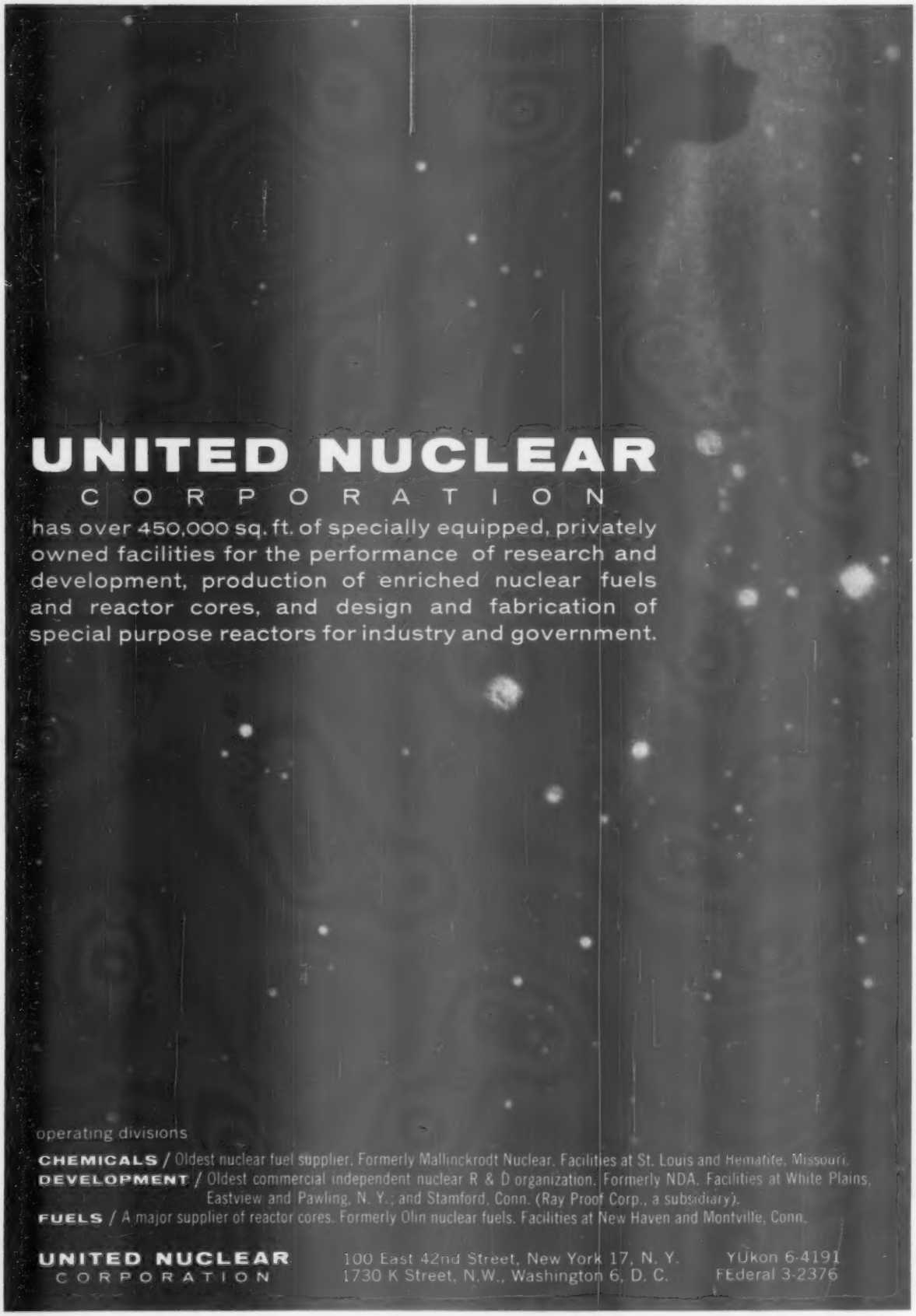
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Generators for NPR Voted Down by House, Up by Senate

In 1956, the Democratic majority of the Joint Committee on Atomic Energy began a relentless agitation for construction of a dual-purpose reactor complex combining military and nonmilitary exploitation of the neutron—to produce both plutonium, for weapons use, and electricity. For a period of five days last month, it looked like their long march toward this goal had been ambushed, primarily on the equally relentless intervention of a young Republican Congressman from California, Rep. Craig Hosmer.

On July 18, however, a 54–36 vote of the Senate restored a $95-million authorization—for electrical generators at Hanford's New Production Reactor—to the AEC's construction-authorization program for the current fiscal year. And, in so doing, the Senate virtually assured, beginning in 1964, the production of as much as 750-Mw of electricity by NPR—thereby putting AEC alongside the Tennessee Valley Authority as a federal producer of electricity.

In a House debate reminiscent of the Gore-Holifield fight in the summer of 1956 (NU, Aug. '56, R1), Hosmer emerged as a forceful and eloquent member of the JCAE minority, leading a coalition of Republicans, southern Democrats and Democrats representing coal-producing areas to a 176–140-vote victory over the proponents of NPR electricity. The vote withholding authorization for the NRP generators had climaxed a campaign which Hosmer had initiated and maintained on his own, until a few weeks before the House voted the generators down.

Late in July, there was still a slight chance that the Hosmer forces—including JCAE members James Van Zandt (R-Penna.) and William H. Bates (R-Mass.)—could block authorization of the NPR generators. However, they were all but conceding defeat after the Senate vote of July 18. From the Senate, the AEC authorization bill was to go to a "conference committee" representing both Houses. The committee, with a Democratic majority, was expected to adopt the Senate version of the bill, with the $95-million NPR authorization retained.

Then, the conference action had to go back to each house for a final vote—with the NPR authorization as part of the entire AEC construction program of $350-million. Thus, the House will vote only on the entire program and NPR cannot be singled out; this was considered a substantial liability for those against NPR's generators.

House Debate

Hosmer, who had been the first to speak out against the Administration-supported conversion of NPR, had begun his campaign in April with a questionnaire to nuclear leaders for their views on generating capacity for NPR (NU Wk, 18 May '61, 6); most, Hosmer reported, were against. At that time, his "voice in the wilderness" was generally expected to go unheeded, particularly in view of the support for NPR conversion from President Kennedy, AEC and the Interior dept. At the same time, there was very little active opposition from the private-utility or other industries which might have been expected to make their influence felt.

By the time of JCAE's vote on the authorization bill, opposition within the Committee had crystallized and a minority report was appended to the majority report, outspokenly opposing AEC's getting into the power-production business.

However, it was the eloquence of Hosmer, with the help of Bates and Van Zandt, that crystallized the surprising majority opposition in the House itself. His principal argument was this: that federal power-production capability should be confined to TVA and that NPR could open the door to unlimited expansion of federal power. Ironically, President Kennedy—only a few days before the House debate—had invited TVA to "go forward" by cooperating with AEC on the development of economic nuclear power.

Rep. Hosmer Almost Blocks NPR Power

"This 800,000 kilowatts of power," Hosmer told the House, "is a large, large bloc of power. It is in addition to some two million additional kilowatts that will be available in the Pacific Northwest on and after 1966 from Libby Dam and as a consequence of the new treaty with Canada.

"Now, that will provide power far in excess of that which can be used in that area. Therefore, it will spawn a demand and provide argument for a power intertie to southern California to connect up the whole Pacific Coast. Already there is a demand for a giant transmission system, to be financed, built and owned by the government in connection with the vast upper Colorado River hydropower development and which would be intertied with Hoover Dam, California and Bonneville power. In time all this would be connected to the Missouri valley, and all of the other public-power areas, by interties. . . .

"If you think this is not a precedent and not the forerunner of many, many more such projects which will make this first $95-million look like peanuts, recollect that only last Tuesday [July 11], in commenting on the TVA, the President of the United States told the TVA directors this: 'I want to see TVA go forward, not rest on its laurels.' He then suggested experiments in conjunction with the AEC to develop cheaper power from atomic energy [TVA is already cooperating with AEC on the Experimental Gas-cooled reactor, which TVA will operate].

"So you see you have the whole TVA getting into this thing and no end of spending from the public till."

Senate Debate

Sen. Bourke Hickenlooper (R-Iowa) led the unsuccessful opposition in the Senate. The brunt of his argument

was that the 1954 Atomic Energy Act did not permit AEC to enter the power business, and that the NPR proposal was thus illegal.

However, the Democrats had virtually assured a substantial Senate majority for NPR by working out an amendment to the AEC bill authorizing $5-million in nuclear studies on coal, thus making the NPR item more palatable to coal-state congressmen. The money would permit studies and design work on coal gasification, radiation effects, etc.

The primary Democratic argument in both houses was that it would be a waste of a valuable resource to dump NPR's heat.

Other AEC Construction

AEC's fiscal-1962 construction program also includes a start on the $114-billion Stanford linear accelerator (15-Bev), for completion in 1964, and an assortment of new and expanded facilities not so expensive. The authorization also provides $7-million in new funds for research-development support of unsolicited power-reactor proposals from the utility industry and $5-million for waiver of use charge on enriched-uranium fuel leased from AEC. JCAE's report on the authorization bill also contained a meaningful comment on acceleration of nuclear power:

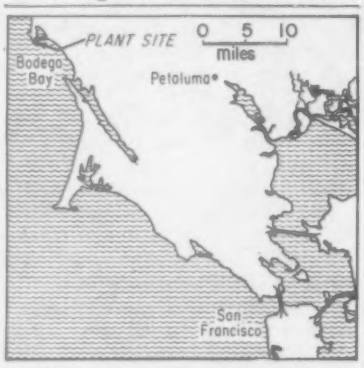
"Following action on the current authorization legislation, the Joint Committee intends to consider what further measures are required to accelerate the atomic power program. It is hoped that arrangement can be made with AEC for mutual consultation in the manner followed in the initial phases of the Joint Committee staff study on the atomic power program in 1958."

JCAE staff officials said they expected to consider acceleration possibilities during the Congressional recess, with the help of consultants still to be selected. JCAE Chairman Holifield has said he would like to see AEC build some reactor prototypes.

PG&E Orders Big Reactor; Southern Cal. Edison Advances

Will Pacific Gas & Electric's 325-Mwe Bodega Bay plant be the world's first power reactor to break the economic barrier? This question had the nuclear industry buzzing last month after PG&E announced that after 16 months' deliberation it had decided to proceed with construction of the biggest boiling-water reactor yet scheduled—and in its announcement gave out some glittering cost figures: 5.62 mills/kwh, $181/kw installed.

In the background, some lesser advances were chalked up by the Southern California Edison 360-Mwe project—born at the same time as PG&E, off to an earlier start in terms of utility decision to build, but hobbled since by site-availability problems. AEC and Westinghouse, designer of the big Edison reactor, were close to final agreement on contract terms, under which AEC would provide $8.7-million research-development aid—plus $7.5-million in waiver of fuel use-charge. (Edison's agreed price with Westinghouse for the reactor is $78-million.) Also, an approach was being worked out to overcome Marine Corps opposition to use of land within the Corps's Camp Pendleton: under it, Edison, backed by AEC, would seek special legislation to make the land available—as a means of discouraging other commercial nibbling away at the Marines' reservation; AEC would also seek Pentagon endorsement before going to Congress.



Bodega: 50 mi north of San Francisco

The Story Is in the Economics

The story of the Bodega Bay reactor is not only that this is—with Southern California Edison—one of the two biggest U. S. reactors announced so far, and one of the only two new reactor starts to be announced by a U. S. utility since June 1959 (Consumers Power Co.'s Big Rock Point, Mich., like Bodega Bay also by General Electric). The Bodega Bay story is in the plant economics: if calculations are borne out in practice, this will be the cheapest nuclear power yet. Estimates are for gross energy generated at the bus-bar with the first core to cost 5.62 mills/kwh, with the second core, 5.32 mills. This compares with conventional steam-plant power costs at the same site of 5.77 mills/kwh with oil at $2.25 per barrel (the present cost), and 6.82 mills with $3/bbl oil—a price PG&E fears is possible by the time the second core would be installed.

Total plant cost is set at $63.8-million: $58.8-million for the reactor plant construction, $2.2-million for voltage step-up, transformers and switching station, and $2.8-million for a transmission line to the PG&E grid at Ignacio, Calif.: total, $63.8-million.

Fabrication of the first core, by GE will cost an additional $8.4-million. No costs are to be allocated to research-development, and PG&E's plant construction costs of $58.8-million are described as a straight commercial quotation with no contribution by GE, the manufacturer. PG&E is not even accepting waiver by AEC of fuel use-charges. "As with all our atomic projects," said PG&E President Norman R. Sutherland, "we will build Bodega Bay with our own money. There will be no government subsidy or financial contribution from any other source."

PG&E's Secret

How can PG&E claim to achieve the goal—competitive nuclear power—that has eluded so many others? The big utility's own answer is that it's primarily because costs are based on 90% plant factor utilization. "There are not many people with a system on which they can run a plant at 90% capacity factor," one PG&E spokesman says. "Utilities back East that can operate only at about 65% capacity factor seem to have difficulty in grasping this basic difference in the nature of the systems.

"We can and do run our steam plants at 90% capacity factor, and will run the Humboldt Bay reactor at 90%, and Bodega Bay too. When you have a system area of 100,000 square miles, where even the time the sun comes up makes a difference in your load, then the unit cost of energy gets pretty low. This is one of the big things we've had going for us in atomic energy; it's just an accident of geography.

"Also, pressure suppression is saving us money.

"We really feel this is the milestone plant. The next one—whether in two years, three, or five—will be ho-hum. This is the last time anyone will be interested in our plans; the next time the world will pay no more attention than when we add another oil-fired unit to a conventional station."

Asked for a breakdown showing how the 5.62-mill/kwh figure was arrived at, PG&E said, "nothing doing." "We won't try to tell how the plant will operate four years before it's

completed, and we won't do our engineering in public," a spokesman said. Despite reported skepticism over PG&E's Bodega cost figures, he went on, the utility's engineers have done enough preliminary work to indicate that it would be worthwhile to bet more than $60-million on success of the plant.

It was emphasized that detailed engineering has not yet been completed, and that the public announcement merely punctuated the continuing planning work on the project. It was also pointed out that the 5.62 figure is "just an estimate" and may very well not hold up. AEC estimated in mid-July that 6.76 mills was a more realistic figure; but AEC used an 80% plant factor and a $61-million figure for total reactor cost.

The Bodega Bay Reactor

The reactor GE has designed for PG&E will be a forced-circulation, direct-cycle boiling water unit with internal steam separation. It will use a core of 75 tons of uranium, 2½% enriched, in the form of uranium oxide pellets in stainless-steel rods, assembled in 592 fuel elements. Estimated in-core fuel life is 3½ years. Pressure-suppression containment will be used again, as pioneered in PG&E's Humboldt Bay reactor: the Bodega Bay unit will be enclosed below-grade in a concrete-and-steel structure 120 ft dia, 100 ft deep. The reactor will supply saturated steam at 1000 psi, 544°F to the tandem compound single-shaft turbine generator. Output will be 325 Mwe gross, 313 net.

GE said Bodega Bay would be "simpler, more compact, more economical and more flexible than previous reactor designs."

Plans are to start construction by August 1962, if all necessary permits are obtained on schedule; this would permit completion late in 1965. PG&E will apply to AEC and the California Public Utilities Commission for permission to build the plant "as soon as circumstances permit," Norman R. Sutherland, president, said. PG&E will function as its own engineer-constructor, as it is doing on Humboldt Bay. (Originally GE made its proposal in collaboration with the Bechtel Corp. as architect-engineer.)

The Bodega Bay Site

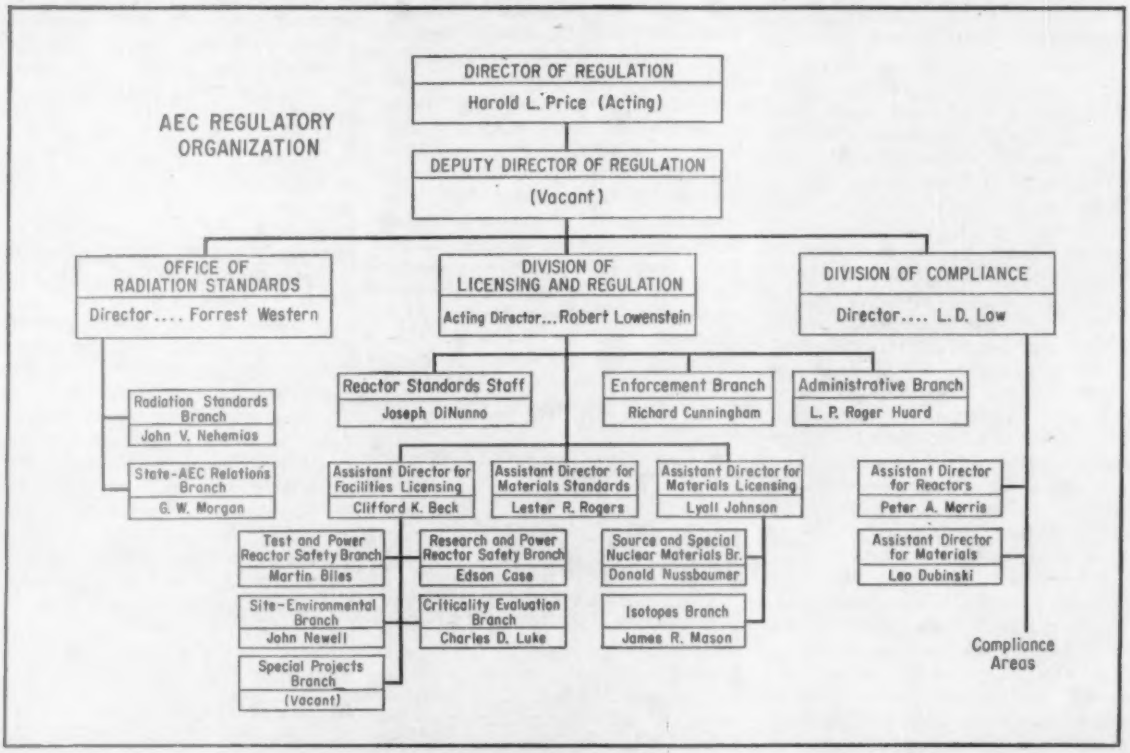
The plant site, 50 mi north of San Francisco on the southern third of the Bodega Head peninsula in Bodega Bay, is a 225-acre tract (PG&E already owns some 160 acres, is negotiating to buy the rest) which the utility will call Bodega Bay Atomic Park. PG&E has discussed the site with the Advisory Committee on Reactor Safeguards—and, it may be assumed, in terms of an eventual site for a multiple-reactor station. Bodega will take a total of at least five units of this size.

Sutherland referred to PG&E's intent to build more reactors when he said, "PG&E's atomic power development program, begun in 1951, always has had large, economic plants as its prime objective. The atom will achieve its important role in energy production when it produces electricity to serve a large and diversified power market as economically and as reliably as available conventional fuels.

"We are convinced that atomic energy can do this at Bodega Bay, taking its place as an economic source of energy alongside natural gas, oil, falling water and geothermal steam to serve central and northern California."

Only six weeks earlier, PG&E Chief Engineer C. C. Whelchel had told the Pacific Coast Electrical Assn. that in his private opinion PG&E would install its last conventional fossil-fuel steam plant in the late 1960's.

AEC Completes Regulatory Reorganization



UPON THE NAMING OF A DEPUTY to Acting Director of Regulation H. L. Price, plus selection of a special-projects chief under C. K. Beck, AEC will complete a several-months' reorganization of its regulatory staff. Price, who reports directly to the five-man Commission, is expected to appoint a deputy of strong scientific capability, emphasizing the technical side of safety review. No further changes in AEC's regulatory posture are expected

INDIAN POINT:

Core Critical in Test Cell

The Indian Point reactor core has gone critical in a test cell at Babcock & Wilcox's Lynchburg, Va., nuclear laboratories. Initial criticality tests confirmed all nuclear design and engineering calculations: "the results came out so perfectly on the nose we're thrilled," a top B&W official said. In addition to confirming calculations, the Lynchburg tests are also providing experience in core-loading procedures.

In making its announcement, B&W claimed a "first": first time a full-scale power reactor using thorium (mixed Th and uranium oxides) had gone critical.

The testing program on the 40-ton, $22-million core will continue until mid-August, after which the core will be ready for shipment to Indian Point, N. Y., whenever the plant, now close to completion, is ready for it.

Con Edison's target date for criticality at Indian Point is "toward the end of this year." "We're hoping for October," a company spokesman said. The utility has begun preliminary discussions with the AEC's Nuclear Facilities Safety Branch as first step in the procedure for obtaining an operating license.

RADIOCHEMISTRY:

Breakthrough in Japan

The first use of radiation to replace conventional catalysts in production of chemicals—a continuous solid-phase process of polymerization by radiation—was revealed last month (NU Wk, 20 July '61). Toyo Rayon Co., a Japanese firm, has been in pilot-plant production, since last January, of polyacetal resin, an irradiated chemical known as du Pont's Delrin in the U. S.

The chemical, intended to replace steel, brass, aluminum and zinc in industrial and commercial applications, is being produced at Toyo's Shiga plant in central Japan through use of a 1.3-Mev Van de Graaff manufactured by Toshiba Electric Co. The plant has a capacity of 10 kg of resin per hour. Key factor in the Toyo method is that polymerization takes place under gamma radiation at temperatures of minus-100°C or lower.

Reason for developing the new process, a company spokesman said, was to get away from dependence on du Pont. (Toyo has been importing 250–300 tons/yr of Delrin from du Pont.) He claimed the new process was much simpler than du Pont's and produces a better product—less affected by heat, neither expands nor contracts, and is rigid but elastic.

Pending Japanese-government patenting of its new radiation process, Toyo plans to build a polyacetal resin plant at Otsu, in Shiga, early next year. The company did not disclose the type or quantity of machines to be used in the production operation.

Toyo is also experimenting with radiation in the production or modification of polyethylene and polypropylene (NU Wk, 6 July '61, 4).

GE SALE:

Zero-power Unit to Japan

General Electric has sold Japan Atomic Energy Research Institute a zero-power reactor for use in providing data for design and evaluation of light-water-moderated and -cooled cores. The critical assembly will use 2.6%-enriched uranium dioxide clad in aluminum; the $600,000 cost includes fabrication by GE of the fuel. Scheduled for completion in July 1962, the unit will be located at JAERI's center at Tokai Mura. It will operate at powers up to 200 watts thermal.

UKAEA:

New Core for Dounreay

The U. K. Atomic Energy Authority plans to load a new core into the Dounreay fast breeder by next spring, Sir William Cook, AEA Member for Reactors, said when AEA's seventh annual report was published last month. The new core, Dounreay's second, would consist of a cermet of Pu and U oxides in a stainless-steel matrix. An alternative arrangement being investigated, he said, was a mixture of carbides in pellet form contained in a stainless-steel jacket. AEA hopes to get the 15-Mwe reactor back into operation by end of August following modifications to the coolant circuit (NU, April '61, 28), and to work the reactor up to design power in the next six months. Sir Roger Makins, AEA chairman, said the Advanced Gas-cooled Reactor was now only three months behind schedule and should go critical early this autumn (NU, April '61, 28).

The annual report contained no policy changes.

EURATOM:

3d Party Liability

The Euratom Council of Ministers finally broke a logjam on third-party liability earlier this month, approving a Euratom Commission formula whereby the contribution of each member nation for liability payment would be based for the first ten years 50% on national income and 50% on the installed nuclear capacity of the country's non-military reactors. This apportionment formula had remained one of the last real obstacles to bringing the third-party liability system into force. One minor difficulty still remaining is agreement on a definition of "military installation." The convention provides that each country would stand responsible to indemnify for damages greater than private insurance coverage, up to $70-million; the Euratom Community would provide a further $50-million indemnity, thus setting up a maximum of $120-million indemnity per accident.

As a result of this action, it is now probable that the Euratom third-party liability convention will be signed before the end of this year. Even before then, other countries of the 18-nation OEEC group will be invited to adhere to it; Austria, Denmark and Switzerland are seen as likely signatories. The Euratom convention will supplement a similar one—but one that establishes only $15-million liability per accident—negotiated last year by OEEC and signed by 16 OEEC countries.

EURATOM:

Merchant Ship Contracts

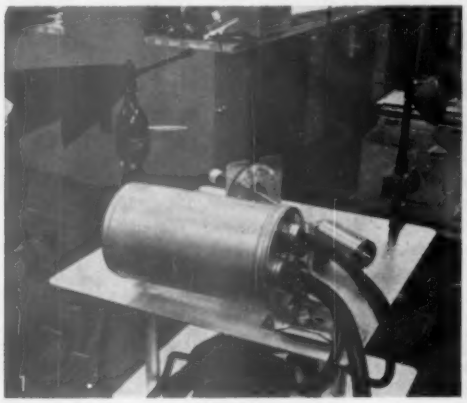
Euratom has extended its activities in nuclear propulsion for merchant ships, with a decision to participate in three research-development projects, to a total tune of $6-million. Announced previously were Germany's organic-moderated reactor propelled bulk-cargo ship project (NU, March '61, 32) and Italy's pressurized-water tanker project (NU, May '61, 26); the Netherlands Reactor Center's study in conjunction with a number of Dutch industrial concerns—perhaps on a boiling-water unit—had previously been mentioned only as a possibility for Euratom assistance. The Community will provide $1.2-million in aid to the Italian, $1.9-million to the Dutch, and $1.8-million to the German projects, which are to extend over two, three, and five years, respectively. Euratom will also act as coordinator of the research work for the three projects, supervise a general research program into the technical problems involved in development of these propulsion reactor types, and arrange for a comprehensive technical and economic study by a group of leading shipping experts on optimum tonnage, type of transport, length of voyage, etc., for nuclear-propelled merchant ships.

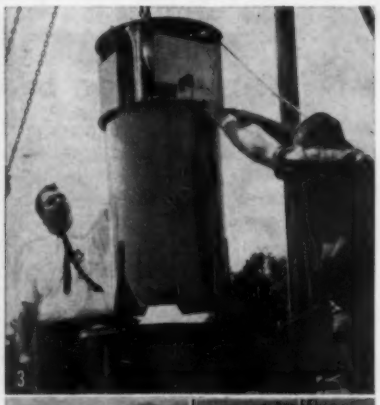
'ENERGY DEPOT':

Allison Gets Contract

Allison div., General Motors, will do a 6-month study for AEC on feasibility of using nuclear power in "energy depots" to support military field vehicles, on a $75,000 contract.

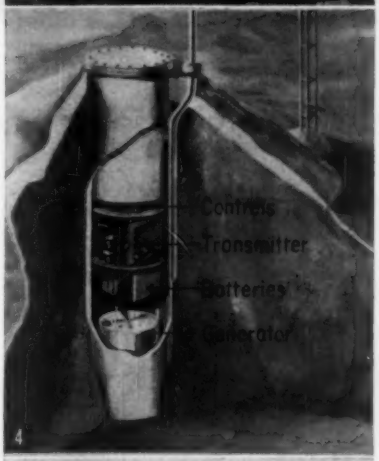
Radioisotopes at Work: Inside the Arctic Circle . . .



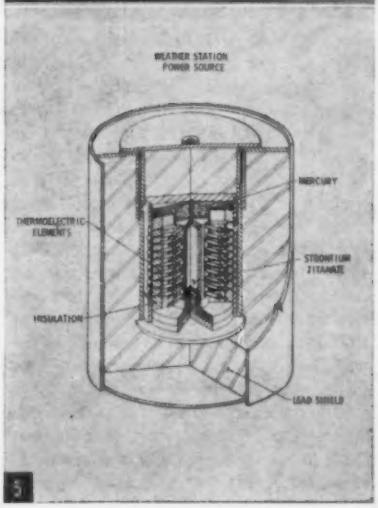


SOME TIME THIS FALL, RADIO SIGNALS like those depicted across the top of this page will be transmitted every three hours from an unmanned weather station inside the Arctic Circle in northernmost Canada. The station power supply is a 5-watt, 17,500-curie, strontium-90 generator charging batteries. With development of the weather station and the plutonium-238 generator already feeding power to the orbiting Transit IV-A (*see photo below*), AEC and Martin Co., developers of both, have climaxed years of farsighted work on radionuclide power and dramatically revolutionized remote and outer-space power. At the weather station (Fig. 4), a tower-mounted wind-direction vane, wind-speedometer and thermometer (Fig. 1) will report to telemetering instrumentation (Fig. 3) in the underground chamber (a barometer is also located underground). The strontium core (Figs. 2, 5) sits at the bottom of the chamber charging batteries just above (Fig. 4). Radio transmission will range from 200–1,500 miles.

The power device for the Navy's Transit (tiny white object in photo) is the prototype of one expected to provide 10-watts-plus for at least 5 years.



. . . and in Orbit, Powering Transit IV-A



BIGGEST HOT SHOP (left) at GE's Idaho plant can handle entire reactors. AERIAL VIEWS of GE/ANP Idaho (center) and CANEL (right) show vast extent of these facilities. (Initials in center photo explained in right-hand column, p. 27.)

ANP Termination Leaves Vast Facilities, Big Technical Legacy

What happens when a program that for 15 years had absorbed much of the nation's best scientific and engineering talent, and consumed $1-billion, is abandoned from one week to the next?

What happens to its people? What happens to its vast, elaborate special-purpose facilities—and what were those facilities, mostly shrouded behind military classification? What among them can be harnessed for other projects? And what of lasting technical value did the project contribute to nuclear technology?

These are all questions that rise when one contemplates the ill-starred Aircraft Nuclear Propulsion program, certainly the most monumental effort in the brief history of atomic energy to *fail* to come to fruition—cut down, ironically, just as it was for the first time in clear sight of its goal.

But on March 28 President Kennedy ordered the entire program terminated, for a variety of reasons—essentially because the nuclear plane lost out in the competition for budget dollars against other weapons systems.

Eliminated were some 6,000 jobs in seven states. 3,060 worked for General Electric, 2,500 for Pratt & Whitney, 250 for Convair, 150 for Oak Ridge National Laboratory, 50 for Lockheed (NU, May '61, 21). GE, harder hit, can keep only 400, has transferred 790 and has had to dismiss 1,450. P&W, thanks to an AEC reactor contract (NU, July '61, 28), can keep 1,450; it has reassigned about 600, 300 have been dismissed or resigned. Staff is now down to 1,600; normal attrition will drop it to 1,450.

Moneywise, P&W got $14.2-million of the $20-million AEC will spend

What Did We Get for our Money? Gen. Branch Answers the $1-Billion Question

At NUCLEONICS' request, Gen. Irving F. Branch, head of the Aircraft Nuclear Propulsion program until his transfer last month to head the Edwards AFB Flight Test Center, cited this list of specific accomplishments that ANP has contributed to reactor technology:

REACTOR SYSTEMS. The Bulk Shielding Reactor was designed and built to get data on large shield components for ANP; world's first swimming-pool reactor, it served as model for dozens of pool-type reactors all over the world. ANP's Circulating Fuel Reactor program at Oak Ridge, in 1954, established the feasibility of the molten salt reactor, now being pursued for civilian application. More recently Pratt & Whitney demonstrated component feasibility of an advanced 2000°F lithium-cooled reactor, promising really compact power packages for ship, airplane, missile or spacecraft propulsion or mobile land use. GE's Heat Transfer Reactor Experiments made numerous advances: HTRE-1 showed feasibility of direct-cycle nuclear propulsion; HTRE-2 with its materials test hole tested fuel elements and solid moderator for HTRE-3, as well as advanced metallic and ceramic fuel; HTRE-3, a closer approach to flight configuration, was the first reactor to use a solid hydrogenous moderator. It demonstrated the ability of concentric-ring metallic fuel elements to operate continuously at temperatures of ~2000°F, with exit air at 1724° from the elements and 1400° from the reactor. A 5-Mwth spherical-geometry reactor was designed, built, and hung from towers at Oak Ridge for a radiation source in shielding development; because of its unique spherical core it has proved valuable in radiation effects work, radiobiology, etc. Zirconium hydride solid-moderator technology spawned the Triga and SNAP-2 and -8 reactor series. Reactor plants were reduced in weight for aircraft service from ~500-1000 to ~100 tons.

FUELS. ANP pioneered work on UO_2 and other ceramic fuels. Development of homogeneous BeO-UO_2 elements was initiated and their feasibility for long-time operation in air established by use of yttrium oxide to stabilize the UO_2. Work underway—vital to the civilian and maritime gas-cooled reactor programs—included determination of the effect of helium buildup in BeO under high neutron flux, to permit predicting the operating lifetime of BeO reflectors, and attempts to develop a UO_2 particle that can be coated by a protective material and fabricated into a fuel-element body so as to prevent continuous release of fission products that contaminate the system. HTRE-3 tests used elements made of metallic sandwich ribbon containing a core of UO_2 dispersed in 80-nickel, 20-chrome alloy with a cladding of 80-Ni-20-Cr; they showed that these fuel elements have the potential for satisfactory operation for at least 300-400 hr at a maximum surface temperature of 1900°F to heat air to 1600°. Extensive testing including 18,000 hr in-pile and 70,000 hr out-of-pile have established the capability of tubular fuel elements containing BeO and UO_2. For the lithium system, too, reliable high-power-density fuel elements were developed and their life and integrity demonstrated under operating conditions in in-pile tests in ETR and MTR; materials included BeO-UO_2, UN and UC. Major effort was in BeO-UO_2, but tests supported use of the nitride and carbide in reactors, promising smaller cores, lower weight, higher burnup and specific power. The metallic dispersion fuel element was first developed under the direct-cycle program; it's been used in the Army package-power program, the Gas Cooled Reactor Experiment in Idaho, and the Sioux Falls nuclear superheat reactor, etc. A high-temperature boron-free braze, now widely used in reactor applications, was developed for use with stainless steel and nichrome.

MATERIALS. The indirect-cycle program produced a high-strength refractory metal—a niobium-zirconium alloy—now available for high-temperature engineering applications; chemically compatible with lithium, it permits design of very high power-density reactors capable of previously unattainable temperatures. As the high neutron absorption cross-section of Li^6 prohibits use of natural lithium as coolant, a process was perfected for production of Li^7 to 99.99% isotopic purity in large quantities at

this year on continuing project work; $4.5-million worth will be done at GE, $1.2-million at Oak Ridge. In recent years the ANP funding level had been around $150-million/yr.

GE was able to save the jobs of 70 top men at its huge Idaho ANP plant when it won the AEC contract for decontamination and core-removal of the stricken SL-1, at the other end of the National Reactor Testing Station; in fact, GE was selected over rivals largely because it was offering to do the job with its top people.

Left over from ANP is a veritable empire of laboratories, research reactors and special testing facilities, scattered almost from coast to coast; a just-completed, never-used ceramic fuel-element fabrication plant; a brand-new hangar bigger than a football field and ten stories high, instrumented to a fare-thee-well, for testing flight-configuration reactor systems; a hot cell bigger than a tennis court and four stories high in which a reactor can be remotely disassembled by manipulators. A rough estimate of the cost of ANP physical facilities comes to about $200-million.

Some have aready been declared surplus. Among them, the 10-Mwth Air Force Nuclear Engineering Test Reactor at Wright Field, just being completed, will be started up, checked out and put on standby; the 10-Mwth unshielded Radiation Effects Reactor at Dawsonville, Ga., has become "government surplus property." Also in limbo are the Tower Shielding Reactor at Oak Ridge, and Convair's Nuclear Aircraft Research Facility at Ft. Worth with two reactors.

But the biggest duchies in the ANP empire are CANEL (Connecticut Aircraft Nuclear Engine Laboratory) and GE's Idaho ANP test site. CANEL, a $63-million plant on a 1200-acre tract just south of Middletown, includes unique facilities that are the finest and most complete in the U. S. for conducting liquid-metal system development. They could be applied to space work as well as to liquid-metal development; for the time being most will be used, though not at full capacity, on the reactor for AEC.

GE's Idaho plant has four main facilities, spread out in the desert: the Assembly and Maintenance building, IETF (Initial Engine Test Facility), FETF (Flight Engine Test Facility), and the Low Power Test and Shield Test Pool Facilities complex. IETF is where, in January 1956, the feasibility of direct-cycle propulsion was first demonstrated by sustained nuclear operation of a turbojet engine. (Since then some 25–30 J-47 engines have been used in tests with the HTRE—High Temperature Reactor Experiment—units.) IETF served subsequently for the tests on HTRE-1 and -2 (metal fueled) and HTRE-3 (ceramic); it was to be vacated by the GE direct cycle project early this year and turned over to P&W for its indirect-cycle reactor experiment. GE was to move to FETF, completed two years ago but never used, for its final direct-cycle pre-flight devices: ACT (Advanced Core Test, an improved ceramic core) and P-140E, a flight-configuration reactor. The Assembly-Maintenance area is where the aforementioned world's biggest hot shop is located, also cold and warm (*slightly* radioactive) assembly bays where components researched, designed, fabricated and subassembled at GE's Evendale, Ohio, ANP headquarters were assembled. Finally there are LPTF with its two critical assemblies for core development and STPF with its Susie pool reactor for super-precise shielding measurements.

acceptable cost. The molten salt program produced INOR-8, a nickel-molybdenum alloy increasing operating life of reactors using lithium-based fused salts; also high-temperature liquid-metal pumps, valves, seals, heat exchangers and instrumentation, used in development of the sodium graphite and liquid-metal-fueled reactors and the Fermi fast breeder. Corrosion data on various alloys with Li, Na, NaK, Pb, Bi, and various fused salts have been obtained and used. Techniques for fabricating large components of beryllium were developed, as were reactor-grade inconel and stainless steels. Yttrium, developed as an alloying material to give strength and oxidation resistance to stainless steel, is now being produced commercially; yttrium-stabilized zirconium crucibles, now used in industry, were developed. Addition of boron to stainless steel and other materials to prevent production of secondary gamma radiation was developed. Use of europium as a control material, and techniques for its fabrication, were introduced. Information on physical properties of lithium hydride for use as a satellite heat sink, as well as on manipulators for remote assembly and disassembly, was harnessed in the space program. Radiation-resistant lubricant research included development of a polyphenyl ether that showed little change in properties under radiation at 425°F for 1000 hr, where normal oils would congeal. Radiation effects on alkyl benzene, dowtherm-A, etc., were determined — origin of the organic-moderated reactor program.

SHIELDING. The majority of free-world shielding research has been done under ANP sponsorship. Results have been used in the maritime, Navy, civilian power, Army package-power, and space reactor programs. ANP pioneered application of electronic computers to shielding calculations; a large number of successful shielding materials have been developed, as well as the principles of divided and shadow shielding.

COMPONENTS. Extensive research on radiation effects on electronic components resulted in development of components able to withstand a radiation environment, such as a high-temperature pulse preamplifier for use up to 690°F under radiation. Great improvements in performance and miniaturization of nuclear measuring devices were achieved. Moving-wire fission gas detectors, high-temperature ionization chambers and fission chambers were developed for making nuclear measurements. High-temperature rhenium-tungsten thermocouples operating up to 3000°F in a 10^{14} neutron/cm² total flux were developed; ceramic-coated wires resistant to high temperatures and radiation were developed for thermocouple leads. Development of electrostatic precipitator systems to filter effluent air from the direct-cycle reactor is of interest to gas-cooled reactor programs for use in preventing contamination of the system. The first large-scale hot-shop for remote work on entire reactors *(photo, top left)* was designed and built.

REACTOR THEORY. Experience in reactor controls was used in developing the control system for the Plutonium Recycle Test Reactor. The first data on nuclear heating rates in material were determined and are now in general use. New methods of power reactor flattening were devised, including a poison wire technique. Several techniques of reactor analysis were worked out and made available, some of them programmed for computer use. Initial work on design and performance of a nuclear ramjet led to Project Pluto; heat-transfer calculation techniques developed in ANP were adapted for use on Pluto.

REACTOR SAFETY. Fission-product dispersal experiments were carried out to determine release, airborne activity, particle size and ground deposition rate of fission products from meltdown of metallic fuel elements: safety margins were demonstrated to be much greater than had been anticipated. Much of the work done on reactor safety, including development of fuse devices, is of value to other reactor programs. So is the basic radiobiological work on physiological reactions and human engineering aspects of keeping men in a radiation environment for long periods of time.

TRAINING. By no means least, ANP was the training ground for a very considerable proportion of the technical people—nuclear scientists and engineers—now working in other areas of the field.

REACTOR NEWS

NEVADA FLIRTING WITH NUCLEAR POWER

A Nevada utility—Sierra Pacific Power Co.—is contemplating building a 75-Mwe reactor between 1965 and 1970 to serve the Reno area. This was disclosed at a two-day forum June 29–30, held by the Fact-Finding Committee on Nuclear Energy for the State of Nevada, to examine the feasibility of using reactor power in that power-hungry state. The Committee, consisting of 13 citizens appointed by Gov. Grant Sawyer, heard presentations by AEC, General Electric, Atomics International, and American-Standard—the first on its new incentive proposals designed to spur flagging interest in nuclear power, the last three on their current offerings in the 50-Mwe range. Purpose of the forum, besides gathering facts, was to stimulate public and industry interest in the possibilities of installing nuclear plants in Nevada, a very high fuel-cost area. The Committee, until now, has been thinking in terms of a series of 50-Mwe stations, fitting in with growth projections over the next several years; it invited the manufacturers' presentations to help in its formative thinking about the feasibility of using nuclear power. And announced publicly for the first time were plans by Sierra Pacific, which serves much of northern Nevada, to build a 75-Mwe reactor near Reno in the decade's second half. Sierra Pacific, which serves Reno, Carson City, and all the northern third of Nevada, had until this year acted only as a power broker rather than power producer, importing electricity from PG&E in California. Since a forest fire last summer cut all three transmission lines, the governor and the public have been putting pressure on Sierra to step up its new construction program.

SIOUX FALLS REACTOR 70% BUILT

Construction of the Sioux Falls reactor is more than 70% complete, according to Northern States Power Co., which will own and operate it. The 66-Mwe reactor, world's first with nuclear superheat, will be in operation next June as scheduled, the utility says. Cost of the Allis-Chalmers unit is placed at $22-million, plus $12-million for research-development, the first five years' operating costs, and the cost of the first core, for a total of $34-million. While this is considerably more than a comparable fossil-fueled plant would cost, NSP Vice President (Operations) Earl Ewald said a second plant could be built for about $16-million, somewhere near the cost of an equivalent conventional plant.

WEINBERG DROPS FIGHT FOR HRE-2

Dropping his campaign to reinstate the HRE-2 program, ORNL director Alvin M. Weinberg has had the aqueous homogeneous reactor experiment mothballed in place after removing its fuel and heavy-water moderator. Following shutdown, project technicians removed and examined corrosion specimens from the core tank, to determine corrosion rates since the fuel flow was reversed and the core tank patched (NU, March '61, 31; April, 29). Citing the corrosion problem as principal reason for shutting down the reactor, Weinberg said ORNL "expects to carry out a small laboratory program through 1962 in continuation of the aqueous homogeneous concept." Project engineers believe that the severe corrosion in local core tank areas could be corrected by proper hydrodynamic design and by proper attention to heat transfer, and that all corrective steps had been taken short of actually replacing the reactor vessel. One project official said that the information obtained as a result of the tests convinced ORNL that it could produce a successful operational homogeneous reactor.

NUSCO TO STUDY YANKEE PERFORMANCE

Nuclear Utilities Service Co. will evaluate the Yankee reactor's performance under a $40,000 contract signed by NUSCo and AEC June 30. Under it, NUSCo will evaluate the operating data available from the Yankee plant, determine if the data available is sufficient for accurate assessment of plant performance, identify any additional data that may be necessary, and compare actual with expected design performance. The work is to be completed this fall. . . Meanwhile William Webster, president of the Yankee group, announced that final costs for the reactor will run $13-million below estimates, thus confirming earlier predictions (NU, March '61, 59; June, 24). Final capital requirements for the project will be about $43.7-million, as compared to $57-million estimated. The plant, which entered regular commercial operation July 1, has generated more than 400-million kwh and performed "somewhat better than had been expected," Webster said. In Washington, AEC amended Yankee's provisional operating license to one expiring Nov. 4, 1997, and authorized increase in power from 392 to 485 Mwth—equivalent to 145 Mwe gross, 136 net.

NS *SAVANNAH* FUELING IMMINENT

The long-awaited fueling of NS *Savannah's* reactor is expected to be carried out early in August. Hold No. 4 immediately forward of the reactor compartment has been turned into a clean-room and fuel vault for the fueling operation; the ship's own cranes will lift the 32 elements one by one from the hold into the reactor vessel. From fueling to initial criticality is expected to require about two weeks, for buttoning up and final pre-critical check-out. . . Todd Shipyards' Galveston plant will be *Savannah's* central servicing site, the Maritime Administration has decided. The plant, on Pelican Island, will be expanded to be able to handle drydocking, repair, maintenance and refueling of the pioneer ship.

LONG BEACH TO SEA; 2 NEW YARDS SELECTED

The Navy's first surface ship, the 14,000 ton, 2-reactor cruiser *Long Beach*, left her builders' yard for the first time at 6:20 am, Wednesday, July 6; traversed Boston harbor, at first under tow; dropped her pilot at 8:14, and took off for the open sea with a dizzying burst of speed. She returned to port Friday, and the Navy reported that "well within the first 24 hours of operation at sea *Long Beach* had completed her design full-power endurance runs; in fact, she exceeded the design requirements." After final outfitting, she will join the Fleet this fall. . . Vice Adm. Rickover disclosed he has started qualifying two more naval shipyards to build nuclear submarines: Puget Sound Navy Yard, Bremerton, Wash., and Charleston (S. C.) Navy Yard. The training of 30–50 of the "very best" engineers and several hundred key workmen in each yard will take at least 1½ years, Rickover said. . . On June 18 the number of operational submarines grew to 21 as *Ethan Allen* successfully completed trials.

4 PAPER-MAKERS EYE PROCESS STEAM UNIT

AEC's 40-Mwth demonstration process steam reactor project drew expressions of interest from four paper manufacturers: Fitchburg Paper Co., Fitchburg, Mass.; Franconia Paper Corp., Lincoln, N. H.; Huss Ontonagon Pulp & Paper Co., Chicago; Shawano Paper Co., Shawano, Wis. AEC is now evaluating data supplied by the firms, and will ask for detailed proposals if its evaluation indicates responsive proposals could be expected.

WORLD NEWS

Eklund Nominated Next Head of IAEA

Arne Sigvard Eklund, director of reactor development for Sweden's national atomic energy company, AB Atomenergi, has been designated second Director General of the International Atomic Energy Agency by its 23-nation Board of Governors. Ratification by the 75-nation annual General Conference, convening Sept. 26, is still required, however, and this is a big hurdle as the Soviet bloc opposed Eklund in the Board of Governors. The Russian choice to succeed first IAEA Director General W. Sterling Cole of the U. S., whose four-year term expires Nov. 30, is Tjondronegoro Sudjarvo, Indonesian delegate on the Board of Governors. Voting against Eklund in the Board were the U.S.S.R., Poland and Bulgaria; neutrals India, Ceylon and Iraq abstained. Eklund's name had originally been put forward by France as a neutral candidate, but the Russians, although reported to hold him personally in high esteem, chose to regard him as a candidate of the Western bloc. Four years ago the Russians accepted Cole's nomination to the top IAEA spot; what position they would take if the General Conference confirms Eklund, and whether they would boycott the Agency's work in such a case, cannot yet be foretold. Eklund needs only a simple majority in the General Conference. He accepted the Board of Governors' nomination just two weeks after it was voted.

Hirsch Sees Wide Use of A-Power by 1970

A European boom in nuclear production of electricity by 1970 was forecast by Euratom's indomitable president, Etienne Hirsch, before the European Parliament of the six-nation European Community. "By 1970 or even earlier," he predicted, "reductions in production costs—resulting from technological progress and improvements rather than from new discoveries—will insure a position for nuclear power that is competitive with conventional forms of electricity production in the Community." When this happens, he said, the European power industry will be in a position similar to that of the aircraft industry on the arrival of jet engines: "Constructors who have not acquired experience and reputation in nuclear techniques will be deserted overnight and left to cater only for the limited circle still able to use those few sources of power still remaining competitive price-wise. . . Mankind no longer faces a power shortage," he went on, "and thrift of power is no longer needed. Therefore we should all go ahead and use up existing reserves of energy before they lose their value by competition of cheaper nuclear energy. Energy supplies will be ensured once European industries have acquired technical competence, and balance-of-payments difficulties resulting from shortage of power supplies will disappear." Hirsch also expressed satisfaction over his new understanding with the U. S. arrived at during his trip to Washington in June: the new relationship "offers prospects for joint activities in a wider field than hitherto."

$32-million Euratom Aid for Power Reactors

Euratom's Council of Ministers approved a $32-million aid program for five power reactors over a two-year period (NU, June '61, 25), in spite of determined French opposition. The plan provides $19-million in fiscal-'61 for the SIMEA and SENN reactors in Italy and the Franco-Belgian SENA reactor at Givet. In fiscal-'62, $13-million will go to aid one German and one Dutch reactor, as yet unspecified. The Council overrode French objections that Euratom's $215-million fund for research and education should be used exclusively for research projects and not stretched to include power.

Allis-Chalmers Gets Swedish Design Study

Allis-Chalmers has gotten a contract for technical investigations and preliminary design for a 56-Mwe boiling water reactor being planned by an eight-utility group, AKV (NU, Dec. '60, 30), for Simpevarp, 200 mi south of Stockholm on Sweden's Baltic coast. Amount of the contract was not announced. Allis-Chalmers' Washington office will carry out the work, with four Swedish subcontractors: Kockums Mekaniska Verkstads AB (conventional plant), Tekniska Byggnadsbyran (constructors); Nyby Bruk (steel) and Svenska Phillips (instrumentation). AKV hopes to make a decision by Jan. 1 whether or not to proceed with construction; the plant, if built, would be scheduled for 1965 completion.

GE in Line for Dutch Study Contract

A second European study contract for a U. S. reactor firm appeared to be shaping up last month, when the Dutch SEP group decided on the boiling-water approach and on General Electric as manufacturer. The Dutch group—which planned an entry in the first round of the joint U. S.-Euratom nuclear power program, but did not make the Oct. 20, 1959, deadline, largely because of high capital cost—has sent a group of engineers to work with GE at San Jose for 3–4 months, to do preliminary design, scoping and economic studies. Present plant size contemplated is about 50 Mwe.

German Jottings

RWE's **Kahl boiling-water reactor** started power production in mid-June, is now operating at 3 Mwe, will reach 15-Mwe full power in a few weeks. Capacity is to be doubled to 30-Mwe at a later stage. . . Bonn is subsidizing not one, but **two OMR design studies** for the KBWP (ex-AKS) group. In addition to the 150-Mwe design study on which Atomics International and Brown Boveri are collaborating (NU, May '61, 26), a second design study on a 15-Mwe version has been ordered from Interatom (German joint subsidiary of AI and Demag) and Brown Boveri. Bonn has granted $443,750 to KBWP to help finance the two studies; their total cost will be $895,500, with the government and KBWP paying 50% each. Both studies are to be finished in 14 months. KBWP will build the 150- or the 15-Mwe reactor, but not both. Decision-making will take three months; thus a construction order may issue by fall 1962. . . . Bonn has also granted a $4.5-million subsidy to the Brown Boveri-Krupp team, builders of the 15-Mwe pebble-bed reactor at Jülich, for **development of a 5–20-Mwe reactor** with higher operating temperatures, better fuel elements, no heat exchanger. Total development cost is put at $6.25-million. It's the first step in the German small- and medium-reactor development program. . . . A 16,000-ton bulk-cargo carrier, not a tanker, will house **Germany's first ship-propulsion reactor.** Reasons: a bulk carrier can be used on shorter routes, making scheduling of any required early repairs easier; dry freight represents a lesser danger-factor than oil.

Belgium's BR-2 Critical

Europe's most powerful testing reactor, Belgium's BR-2, went critical June 29. Owned by Centre d'Etude de l'Energie Nucléaire (and designed by NDA, now part of United Nuclear Corp.), it was scheduled to go critical by end-1958 (NU, '56, 13). The $20-million, 50-Mwth unit will have 10^{15} peak thermal flux in its central hole.

NEWS IN BRIEF

Oak Ridge Asks to Take On Major Nonnuclear Effort

The first formal request by a national laboratory for assignment of a nonnuclear project has been submitted to AEC by Oak Ridge National Laboratory. Alvin M. Weinberg, ORNL director, has asked permission to take on an ambitious water-resources-development program, including desalinization, underground exploration, conservation, etc. His request was particularly timely because it was tendered as: 1. officials of the new Administration—particularly President Kennedy and AEC Chairman Glenn T. Seaborg—were giving their support to the use of national-laboratory resources for public-interest projects outside the nuclear field (NU, July '61, 26); 2. the labs were feeling pressure from both reduced budgets and the continuing industrial campaign to get AEC-funded work industry is capable of handling (NU, May '61, 24); and 3. the nation, as a whole, was taking a greater interest in future water resources.

Primarily because the ORNL proposal is a "first," however, it has raised many fundamental questions which must be ironed out in Washington. How should a nonnuclear program at a heretofore-nuclear lab be managed from Washington—through AEC? by or with the federal agency more directly involved? How far should a lab be permitted to go in allocating manpower and facilities to nonnuclear work? How should the work be financed? These questions were being discussed at top policy levels and answers to them were estimated by some at being "miles off." However, because of the Kennedy and Seaborg interest in seeing the labs get into such things, the Weinberg proposal is considered "more than a dream."

AEC Drafting Measure to Limit Mandatory Hearings

AEC disclosed last month that it was drafting a proposed amendment to the 1954 Atomic Energy Act to modify the existing requirement for mandatory hearings in reactor-licensing cases. General Counsel Neil Naiden's office working up a measure to limit formal hearing to one—at the construction-permit stage—with additional hearings to be scheduled only on request of intervenors or on the Commission's own initiative. This alternative to the present mandatory requirement had been proposed pretty generally in June, during hearings of the Joint Committee on Atomic Energy on nuclear regulation and safety (NU, July '61, 23). There was some question whether an amendment to the 1954 Atomic Energy Act could be approved by Congress so late in the current Congressional session but, because of the widespread agreement on modifying the mandatory-hearing requirement, there is a possibility of action on the AEC proposal before Congress adjourns late this month or early next (*related story page 23*).

AEC Holds First Public Meeting on Reactor Project

On June 19, AEC conducted its first public meeting at the site of a proposed reactor and the "experiment" went off without controversy. In fact, it went so well that AEC Regulation Director Harold Price (*see chart page 23*) said last month that the program would probably be continued, and, it was indicated, the second such meeting will probably be held near the Pennsylvania site of the Peach Bottom, high-temperature, gas-cooled reactor. The June meeting was held in Pleasanton, Calif., near the Vallecitos Laboratory of General Electric Co., where GE has proposed construction of the experimental superheat reactor sponsored by Empire State Atomic Development Associates (NU, Jan. '61, 20). AEC speakers at the two-hour session were Robert Lowenstein, acting director of the Division of Licensing and Regulation, and Clifford R. Beck, assistant director for facilities licensing; Lowenstein covered AEC's regulatory program and Beck discussed the safety of the proposed plant.

Though the meeting was quiet, there was some doubt of its value as a guage of a successful experiment, because: 1. only a handful of the estimated 75 attendees were private citizens not involved with nuclear energy, the rest being GE nuclear people, local or state officials and AEC personnel; 2. the Pleasanton area is conditioned to nuclear power, which is almost considered "old hat" there. A formal AEC hearing on the superheat plant was held on June 29, with the AEC staff giving their endorsement, and the issuance of a construction permit was expected routinely.

Armstrong Leaves AEC; Will Join Rocketdyne . . .

Col. Jack Armstrong, formerly deputy director of AEC's Aircraft Nuclear Propulsion Office and recently slated to take a post of associate director in AEC's Reactor Development div., has left AEC as of June 30. He said he had accepted a nonnuclear post with Rocketdyne div. of North American Aviation, Inc. Personality differences, particularly with AEC General Manager Alvin R. Luedecke, appear to have led Armstrong to leave Washington. Before he left there were these major developments involving Armstrong: 1. he was awarded the Legion of Merit by Air Force Secretary Eugene Zuckert, in a ceremony at the Pentagon; 2. the U. S. successfully fired into orbit a SNAP device of the type which Armstrong had done much to pioneer as manager of the SNAP program (Systems for Nuclear Auxiliary Power); and 3. he had had a major role in drafting the plans for reorganizing AEC's Reactor Development div. (NU, June '61, 21). During his five years at AEC, Armstrong had important policy and managerial roles in the nuclear airplane, ramjet, rocket and SNAP programs. Since last September, he had been working directly for Reactor Development Director Frank Pittman on the proposed reorganization, on advanced-reactor concepts and, since this past spring, on SNAP. No one had been named, as of late last month, to the associate director's post for which he was in line.

. . . and Ramjet Manager Branch Also Leaves AEC

Also involved in the personality friction which had been the prime reason for Armstrong's resignation was Brig. Gen. Irving L. Branch, two-hat manager of the nuclear-ramjet and nuclear-airplane (before this project was killed by the President). Branch has been transferred by the Air Force to Edwards Air Force Base, Calif., where he was to assume command of the Flight-Test Center on Aug. 1. Simultaneously with Branch's departure, AEC and the Air Force have agreed to abolish joint management of the reactor portion of the nuclear-ramjet program (Project Pluto) for the indefinite future. AEC will direct development of the Pluto reactor, with Irving Hoffman continuing to have direct responsibility within the Division of Reactor Development; Hoffman will probably report to the successor to Col. Jack Armstrong (*see above*), when a successor is named. Col. Ola P. Thorne, former deputy to Branch, has succeeded him at AF headquarters; Thorne will direct all AF interests in nuclear energy, including development of a nuclear-ramjet engine and vehicle.

A review of the ramjet program is to be completed by Thorne's office this month. Success of the first ramjet reactor test in May (Tory II-A prime) has led to the possibility that engine development may be accelerated.

RADIATION NEWS

HVEC Subsidiary Wins Plastics-Irradiation Patent

The impact of an "extremely broad and inclusive" patent on the electron-irradiation of plastics issued Apr. 25 (NU Wk, 29 June '61, 1) to Electronized Chemicals Corp., High Voltage Engineering Corp. subsidiary, was still unclear, an HVEC/ECC spokesman said last month. ECC has notified all producers of irradiated-plastics that their activities may be subject to licensing. These include General Electric Co., both a producer of irradiated plastics and a manufacturer of radiation machines; Raychem Corp., producer of several irradiated plastics; and Cryovac div. of W. R. Grace & Co., pioneer in the development and marketing of irradiated-plastic wrapping film. Some of those notified have already responded, HVEC officials said. In general the respondents said that they would study the patent before responding more definitively. Raychem Corp., engaged almost entirely in the irradiation of plastics, told NUCLEONICS: "We are aware of the existence of the patent and we are studying it closely." An official of another firm, however, said he interpreted the development as meaning that "anyone who irradiates polyethylene, in any form, must get a license from HVEC/ECC." However, the patent covers specific radiation dosages—with a minimum of one megarep—and, presumably, processes involving less than this would not be covered.

HVEC/ECC have been proceeding cautiously, with the over-all aim of trying to establish nonexclusive licensing arrangements while, at the same time, wanting to do nothing to impede the growth of radiation in the thermoplastics field nor to encourage litigation over the patent. They made it clear, however, that the patent was considered a prospective source of licensing revenue: "We would like to license people and get some royalties out of this. . . . We would like to have as many people as possible sign up." GE challenged the priority of the patent before it was granted but is not expected to challenge the patent in the courts because, in having sought a similar patent, GE is already on record as considering the ECC patent valid.

The scope of the patent, originally sought in a February, 1954, claim filed by Arno Brasch, is contained in its wording: "The principal object of the present invention. . . . is to provide a process for greatly increasing the physical and chemical resistance of certain thermoplastic substances. . . . it will be seen that articles can be molded from a wide range of thermoplastic polymers in the conventional manner, and then these articles can be treated by electron bombardment so as to produce changes which frequently greatly improve their physical and chemical characteristics for certain purposes."

Tracerlab Merging with Laboratory for Electronics

The firm which has given birth, directly or indirectly, to a large percentage of the nuclear-instrument industry, Tracerlab, Inc., has decided to merge with Laboratory for Electronics, subject to stockholder approval later this summer or in early fall. Tracerlab will thus relinquish its independence for access to much-needed cash for expansion—after a several-year period of financial and other problems. Although both boards of directors had approved the merger as of early last month, few details of the arrangement had been worked out.

Tracerlab is expected to operate as an LFE subsidiary but there was conflicting evidence on whether S. S. Auchincloss would stay on as Tracerlab president. Moreover, because of the divergent interests of the two firms (LFE had been doing 90% of its business with the government in air navigation systems, radar, etc.), integration of their production sales, and other capabilities was not considered likely in the foreseeable future. Primarily, LFE's interest was in the acquisition of a firm doing substantial commercial business (85% of Tracerlab's sales) and Tracerlab needed expansion capital ("Sales are at as high a rate as ever but we need cash for advertising, sales promotion and expansion of the product line."). LFE's sales are about $50-million annually; Tracerlab's sales were $12.5-million last year.

GE Sells Two Radiation Machines for Textiles

The sale of two electron-beam resonant transformers for research on and pilot-plant production of textiles was disclosed in late June by General Electric's X-ray dept., Milwaukee, Wis. The purchasers were two undisclosed customers overseas, one purchasing a 1-Mev machine, the other a 2-Mev unit. GE and other radiation-industry officials were excited about the purchases, primarily because they indicated an economic breakthrough in the radiation-processing of synthetic textiles—a particularly promising market for radiation sources.

In a related development, Radiation Dynamics, Inc., which had announced the sale of a 1.5-Mev Dynamitron accelerator to a Japanese textile firm last year, said it expected to ship the machine to Japan this month.

Large Medical Supplier Orders Irradiation Plant

Becton, Dickinson and Co., East Rutherford, N. J., confirmed last month that it had ordered a complete radiation-sterilization plant from Hughes Aircraft for scheduled operation by the end of the year (NU, June '61, 27). B-D and its subsidiaries operate plants in the U. S. and abroad manufacturing medical instruments, thermometers, hypodermic needles, syringes, etc. The Hughes plant, featuring a 10-Mev linear accelerator, would be located in East Rutherford. B-D refused to divulge other details "until it is working properly."

Hughes Expands. Meanwhile, Hughes disclosed that its Nuclear Electronics' Laboratory was moving to expanded quarters at Fullerton, Calif., 30 mi from the former location at Culver City—in a move reflecting greater confidence of the management in the Lab's activities. These include development of accelerators, solid-state detectors and remote-handling equipment—all associated with radiation and its effects. The Lab is joining the Hughes Ground Systems Group at Fullerton and expects to develop a major radiation facility there.

New Firm Enters Radiation-Detection Field

Industrial Electronic Hardware Corp., a New York City manufacturer of electronic components, has entered the radiation-detection field with a Navy procurement contract for 200,000 personnel dosimeters to be delivered to the Marine Corps early this fall. The company is also in the process of developing three more radiation instruments: 1. a thermoluminescent dosimeter, 2. a pencil-type self-indicating dosimeter, and 3. a radiac meter (essentially a sensitive Geiger-Mueller counter). The company plans to use $150,000 of a proposed $1-million bond issue for tooling up and production of the dosimeters. The units are waterproof, are designed primarily for combat personnel (1–600 r), and will cost approximately $2.00 apiece. They are made of two disks of plastic-enclosed lead, surrounding a disk of radiophotoluminescent, heat-treated glass which can be removed for reading in a separate roentgen-reading machine. The design is a modification of a dosimeter developed by two Naval Research Laboratory scientists—James H. Schulman and Robert J. Ginther (NU, Apr '60, 92; Oct '53, 52).

SPACE NUCLEONICS

July Big Month for Rocket-Engine Development

NASA last month invited architect-engineer proposals on the first nuclear-rocket-engine facility—a maintenance, assembly and disassembly building to be located at the National Nuclear Rocket Development Center, Jackass Flats, Nev.; 19 firms were invited to reply by July 24. Also, before the month was out, the joint AEC/NASA Space Nuclear Propulsion Office, under Harold B. Finger, was to complete negotiations on the six-month Phase 1 of an engine-development contract with Aerojet-General Corp. (NU, July '61, 25). Westinghouse Astronuclear Laboratory is subcontractor to Aerojet for all nuclear work, AMF Atomics for assembly, disassembly, etc., and Bendix Aviation for actuators and controls.

Soviet Lead in Electrical Propulsion Reported

NASA officials reported in late June that the Soviet Union, according to authoritative information reaching the U. S. appears to be well ahead of the U. S. in development of nuclear-electrical propulsion engines for space. The NASA revelation came shortly before officials of the House Science and Astronautics Committee disclosed that it will probably carry out a study of the U. S. electrical-propulsion effort during the upcoming Congressional recess; the study would probably be followed early next year by a series of public hearings on the program. NASA officials, clearly shocked by their discovery that the Soviet Union may have an operational nuclear-electrical spacecraft of several hundred kilowatts in 1964, urged a several-step acceleration of the U. S. effort, which is now paced for operation of an engine of only 30–60-kw no earlier than 1966 (SNAP-8). A combination Saturn chemical booster and 300-kw electrical spacecraft could deliver five times the payload of an all-chemical system to the vicinity of Mars, NASA estimates, although the trip would take four times as long. However, a 1-Mwe electrical-propulsion system could deliver eight times the payload of a chemical system in only three times the period.

The following broadening and acceleration of the U. S. effort has been urged within NASA: acceleration of advanced-system development beyond SNAP-8 to hasten 300–1,000-kw, high-temperature engines (*see below*), with these systems being developed specifically as upper stages of Saturn or Nova chemical boosters; development of 60-kw systems for integration with the Centaur rocket; and development of 30-kw arc-jet systems for earth orbital missions (communications, etc.).

3 More NASA Contracts on Electrical Propulsion

Three more contracts have been let by NASA within its program for developing high-temperature technology basic to advanced nuclear-electrical propulsion systems (NU, Feb. '61, 82). Program manager is Lewis Research Center, which has given contracts to: Development div. of United Nuclear Corp. (formerly NDA) for design and fabrication of a 1-Mwe, liquid-metal, heat-transfer loop for all-liquid and boiling experiments with potassium, sodium, etc. ($533,000); AMF Atomics for design, fabrication, installation and test of a sodium vaporizer and turbine loop (second stage of a contract totalling $600,000–700,000); and Pratt & Whitney's Connecticut Aircraft and Nuclear Engine Laboratory (CANEL) for construction of a test stand at Lewis for development of space radiators and condensers ($589,000). To be completed by October, 1962, the stand will include a space-environment chamber 8 ft in dia and 18 ft long and a closed-loop system capable of dissipating heat up to 1,800 deg F.

Liquid-Metal Contract Won by Univ. of Michigan

The Aeronautical Systems div., Wright Patterson Air Force Base, has given a $199,000 contract to the Univ. of Michigan for the study of heat transfer of boiling liquid metals in small reactors, primarily for space. The Wright division has been involved in the AF contracts with AiResearch div. of Garrett Corp. (prime) and Aerojet-General Corp. on Project SPUR (Space Power Unit Reactor), looking toward development of 300-1,000-kwe reactors for electrical propulsion and auxiliary power (*note NASA story above*). Thus, both NASA and the AF are supporting research-development on components, working fluids, systems, etc., for high-temperature, high-powered space reactors.

The Univ. of Michigan contract includes studies of sodium, potassium, mercury, lithium and rubidium to learn more of the boiling process of these liquid metals and of the effect of varying gravitational fields on the process. The campus group involved, working under R. E. Balzhiser, will also "attempt to establish all the procedures and technical design criteria necessary for future design and development of liquid-metal boilers."

Use of SNAP Device in Surveyor Likely

The likely selection of a radioisotopic-power generator for NASA's Surveyor program for landing instruments on the moon has emerged in the aftermath of last month's successful orbiting of a strontium-90 generator in Transit IV-A (*page 25*). No official decision had been announced as of last month but all unofficial signs pointed toward use of a curium-242 device in the 15–25-watt range for the Surveyor series. Manager of Surveyor is NASA's Jet Propulsion Laboratory, which has been quietly enthusiastic about radioisotopic generators (NU, Apr '61, 57) but has not, until the Transit shot, been able to argue effectively for radiation power against solar or fuel cells in combination with batteries. However, as an AEC official emphasized shortly after the Transit test, its success has given substantial support to JPL and other advocates of nuclear devices for auxiliary power involved in projects where nonnuclear devices cannot be expected to perform as well. NASA [and others], have been waiting for someone else to do it first.

A curium device would offer three major advantages to the Surveyor series (Surveyor, beginning in 1963, would soft-land instrument and communications systems on the moon to analyze ambient conditions and drill into the crust). A substantial weight saving over power systems using batteries would provide an opportunity to put more instrumentation into the Surveyor spacecraft; also, a curium device offers both longer lifetime (two months as against about two weeks) and more rugged construction than battery systems. Martin Co. has been developing a curium generator under AEC contract (NU, July '61, 32).

California Firm Gets Plasma Contract from NASA

NASA has given a contract "in excess of $100,000" to Clauser Technology Corp., Torrance, Calif., for feasibility studies on a magnetic induction plasma engine for interplanetary-space travel. The contract covers construction and test of both single- and repetitive-firing engines utilizing the interaction force between a traveling magnetic field and a gaseous plasma. President of the firm is Milton Clauser, formerly of Space Technology Laboratories and Purdue Univ.

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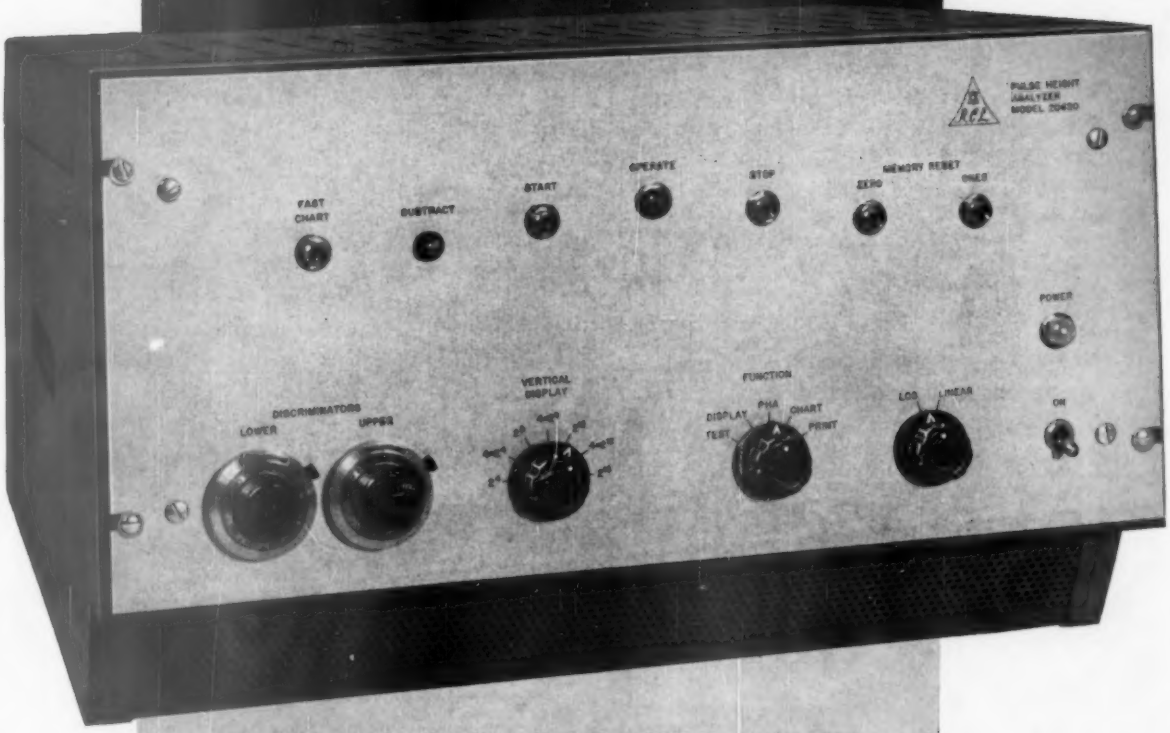

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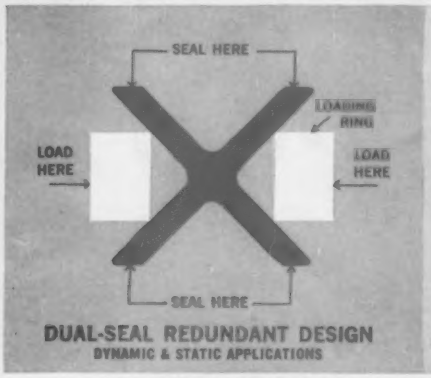

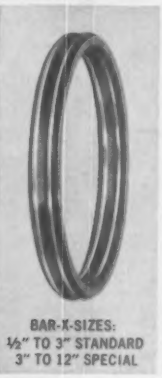

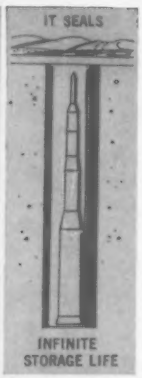

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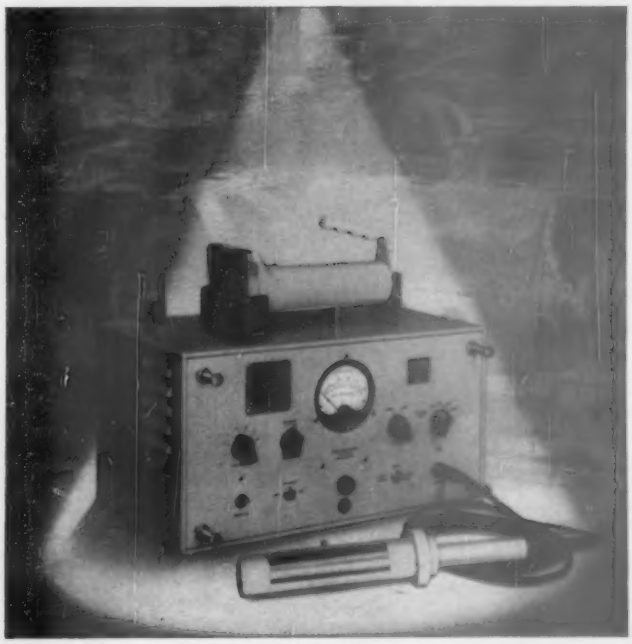

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WATER-COOLED TUBULAR CONDUCTOR

...vital part of unique stabilizing winding for C Stellarator!

Phelps Dodge water-cooled tubular conductor is a critical part of the unusual helically coiled field windings being made and to be installed in the experimental C Stellarator device at Princeton University by Allis-Chalmers Manufacturing Company.

The hollow conductor is extruded and drawn from high purity oxygen free copper. Set within the conductor is an off-center hole for converging a liquid coolant, needed to dissipate the intense heat generated by high currents in the coils of the C Stellarator.

Phelps Dodge has pioneered and developed the design and manufacture of off-center tubular conductors. As a result, only Phelps Dodge produces these tubular conductors in a variety of shapes to fill a wide range of requirements.

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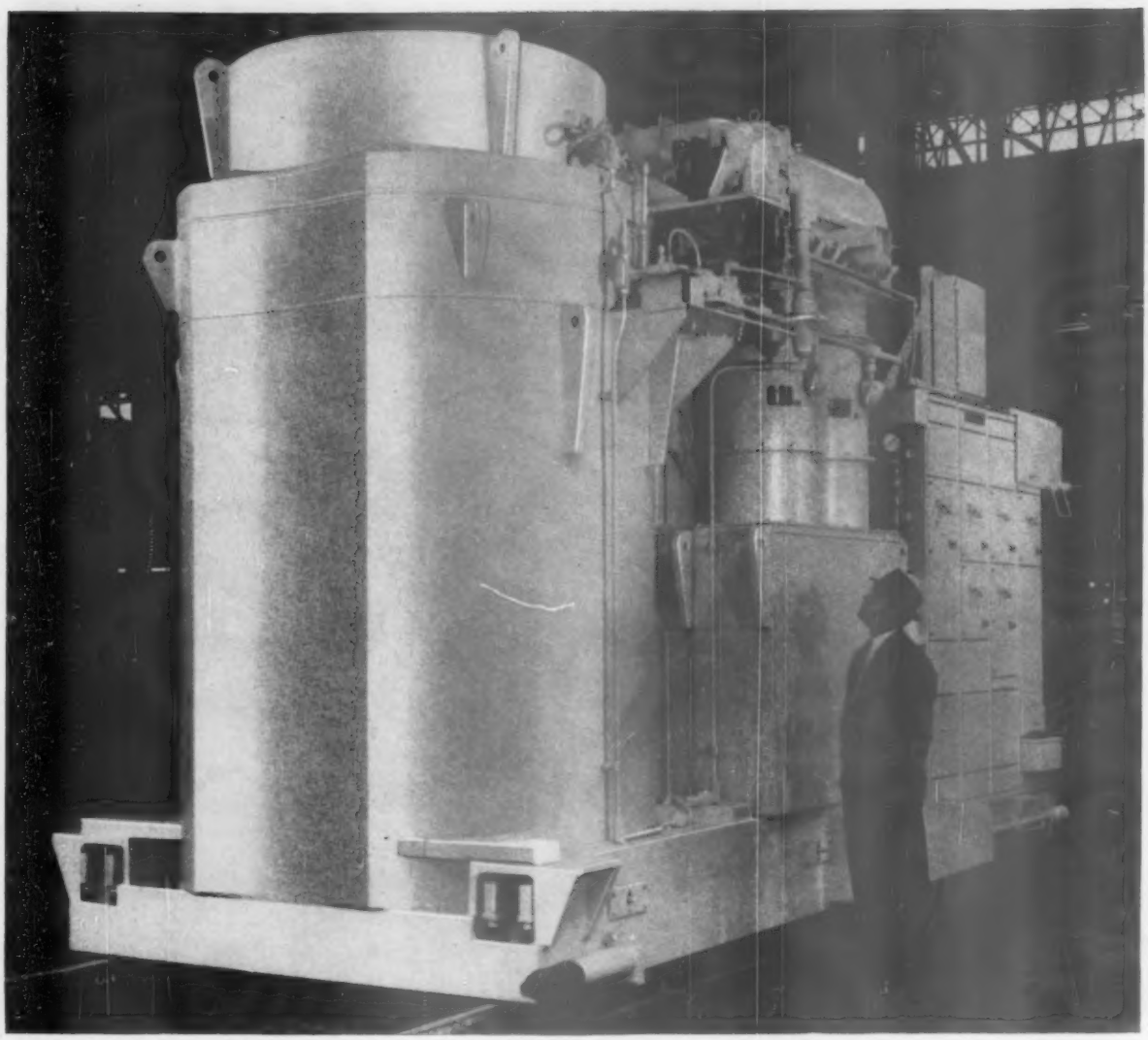
P MINE TO MARKET D



Fuel transfer cask car shown in plant of its builder, Baldwin-Lima-Hamilton, Philadelphia, prior to rail shipment to Enrico Fermi Atomic Power Reactor, near Monroe, Michigan. The car, 22′ long, 10′ wide, 13′ high, weighs about 200 tons. Gamma shielding by National Lead Company consists of about 170 tons of lead and about 7 tons of depleted uranium. Power Reactor Development Company built the nuclear portion of the plant in which this unique vehicle will operate, and Detroit Edison Co. constructed the turbine generator section.

You get more than metal in gamma

You get two exclusive built-in extras: the *result* of the lead handling know-how of the world's largest fabricator of lead products... the *effect* of the mutuality of interest engendered by National Lead's own activities in the nuclear industry.

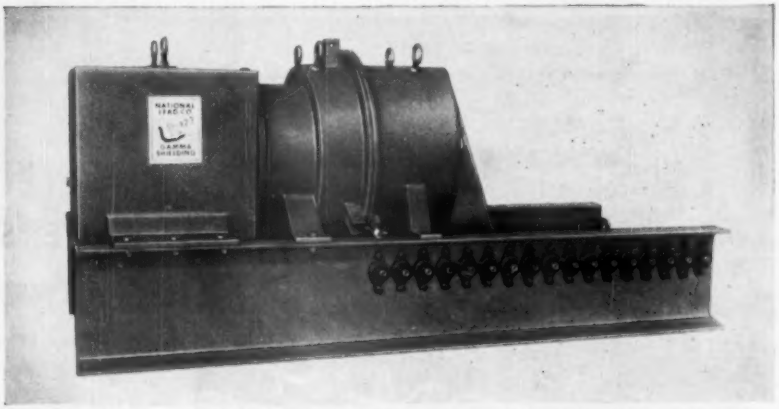
Working with lead for many years in many fields, National Lead has built up a vast fund of experience in handling the metal. This know-how is expressed in lead grade selection, alloying practices, fabrication methods, casting temperatures, cooling rates, bonding techniques and other areas vital to quality. Thus, National Lead knows how to make the most of lead's gamma attenuation properties.

The other built-in extra is the "feel for the function" of the shieldment. The design, engineering and production of National Lead shielding benefits by the supervision of men thoroughly versed in nuclear arts and sciences. National Lead has its own Nuclear Metals Division, is a co-owner and operator of Industrial Reactor Laboratories at Plainsboro,

Fuel handling device built by Atomics International for the AEC, to be used at the Hallam, Nebraska, reactor operated by Consumers Public Power District. Among many other functions, this 54′ high, delicately controlled machine deposits and retrieves fuel rods when positioned over the reactor. Gamma shielding of the device consists of 118 tons of National Lead Company's lead shot.

"Hi-Hard" lead brick, about two tons to a pallet, being prepared for shipment on an order totaling 100 tons. Since introducing "Hi-Hard" some years ago, National Lead has supplied large tonnages of these bricks, in several sizes and shapes, for gamma shielding installations around the country. Having a Brinell hardness of around 20 (as against about 4 for regular lead), "Hi-Hard" brick withstands considerable handling abuse before consignment to the discard pile. With a small mark-up over the regular brick, the "Hi-Hard" variety is a real buy for any purchasing agent.

Transfer cask. This 8-ton cask and 12 storage shrouds were built by National Lead for the Indian Point Generating Station of Consolidated Edison Co. of N. Y., Inc.



CO-60 irradiator produced for Republic Electronics Industries Corp., Farmingdale, L.I., New York, by National Lead.

shielding supplied by National Lead

New Jersey, operates for the AEC the Fuel Materials Production Center at Fernald, Ohio, and the Research Laboratory at Winchester, Massachusetts. In many important ways, these interests are reflected to the customer's benefit in gamma shielding designed and produced by National Lead.

* * *

When you need shielding, whether of lead or depleted uranium, off the shelf or made to order, get in touch with our nearest Branch.

This trademark is the symbol of National Lead Gamma Shielding.

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Our newest **SCINTILLATION PHOSPHORS**

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- **High Temperature Plastic Phosphor NE160**
  For measurement at temperatures over 100°C.
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  For safe, economical, giant liquid scintillator installations.
- **Liquid and Plastic Scintillators**
  For the challenging technique of Pulse Shape Discrimination.
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  Premixed solute combinations for convenient dependable preparation of liquid scintillators for internal counting.

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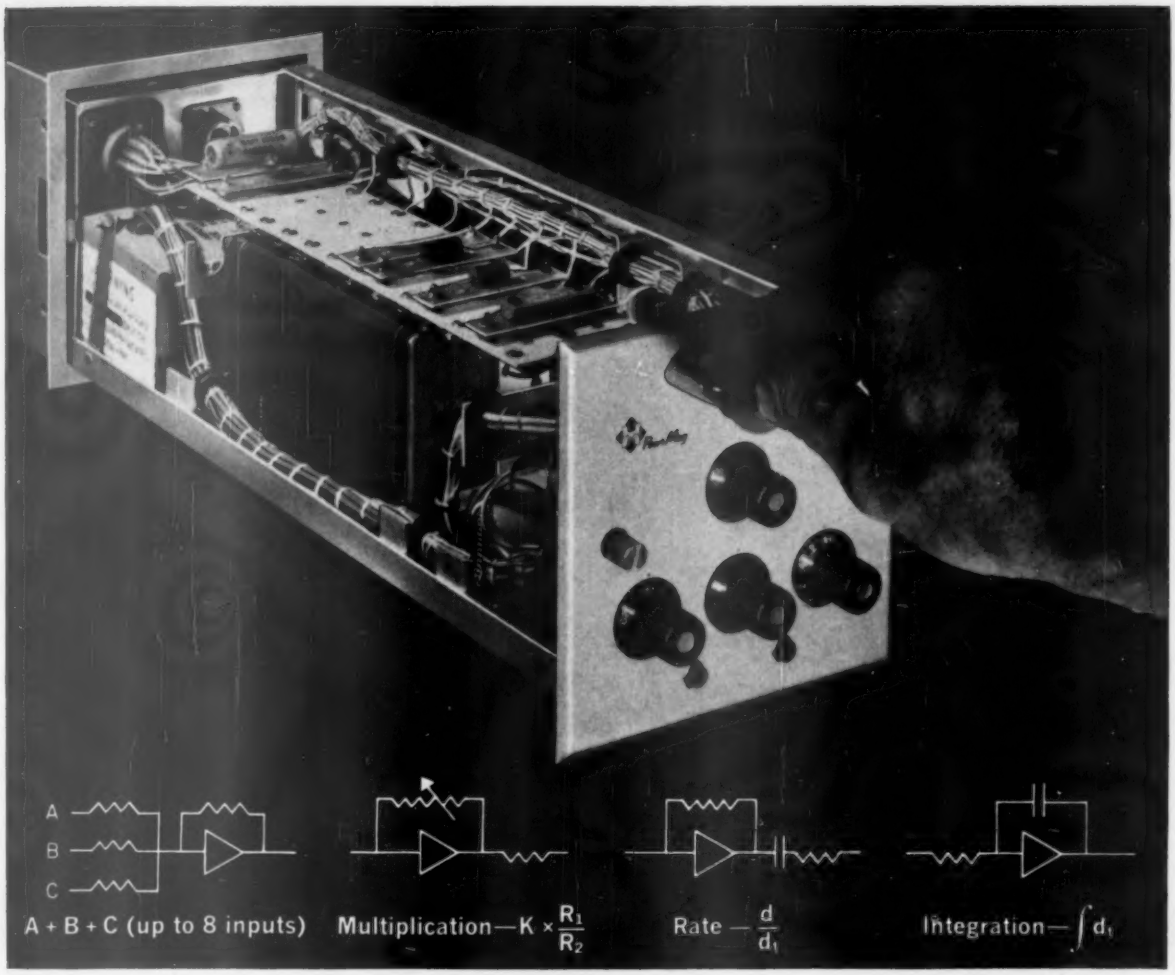

for Atomic Power Plants... Hagan PowrMag® Controller—solid state reliability

Hagan's PowrMag controller combines the kind of reliability required by atomic power plants with a flexibility of application that makes this one controller suitable for all control actions. Utilizing a high gain, operational magnetic amplifier, PowrMag can produce the full range of control actions by simple negative feedback through ordinary resistors or capacitors. These "passive network" elements are simply and easily plugged into the basic amplifier chassis by means of an integral plug-board, as shown in the photograph.

The PowrMag system uses high level control signal DC voltages which eliminates noise, capacitive loss and phase shift problems. This electrical transmission of sensing unit signals as well as control signals eliminates the use of pneumatic lines in problem areas. The entire amplifier is first potted, then cased in steel. Since any unit can perform any control action by a simple change of plug-in components, inventory and stocking problems are eliminated. Power supply is unregulated 110vAC, and power consumption is three watts.

Each module is equipped with a pilot light to indicate fuse failure, test jacks to plug in an output meter, calibrated knobs for set point (bias), gain, reset and rate. Controller components can be replaced without a soldering operation.

The complete PowrMag line includes the controller, remote control stations, sensing elements, and final operators. For information on the application of Hagan equipment to atomic power plants, write or phone NUCLEAR POWER DIVISION, Room 808, Hagan Center, Pittsburgh 30, Pennsylvania.

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THIS GENERAL ELECTRIC BOILING WATER REACTOR PLANT is conventional in appearance, economical in certain high-fuel-cost areas.

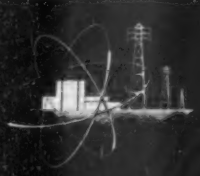
A FULL LINE OF NUCLEAR PLANTS TO 500,000 KWE

General Electric BWR plant cost equals conventional plant cost in certain areas

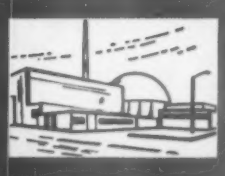
General Electric is now offering a full line of boiling water reactor nuclear power plants rated up to 500,000 kwe. These new plants will be competitive with, or more economical than, conventional plants in certain high-fuel-cost areas.

These advanced designs are now possible because of information from testing and operation of Commonwealth Edison's Dresden Nuclear Power Station, and other results from continuing technical development programs with electric utilities and the Atomic Energy Commission.

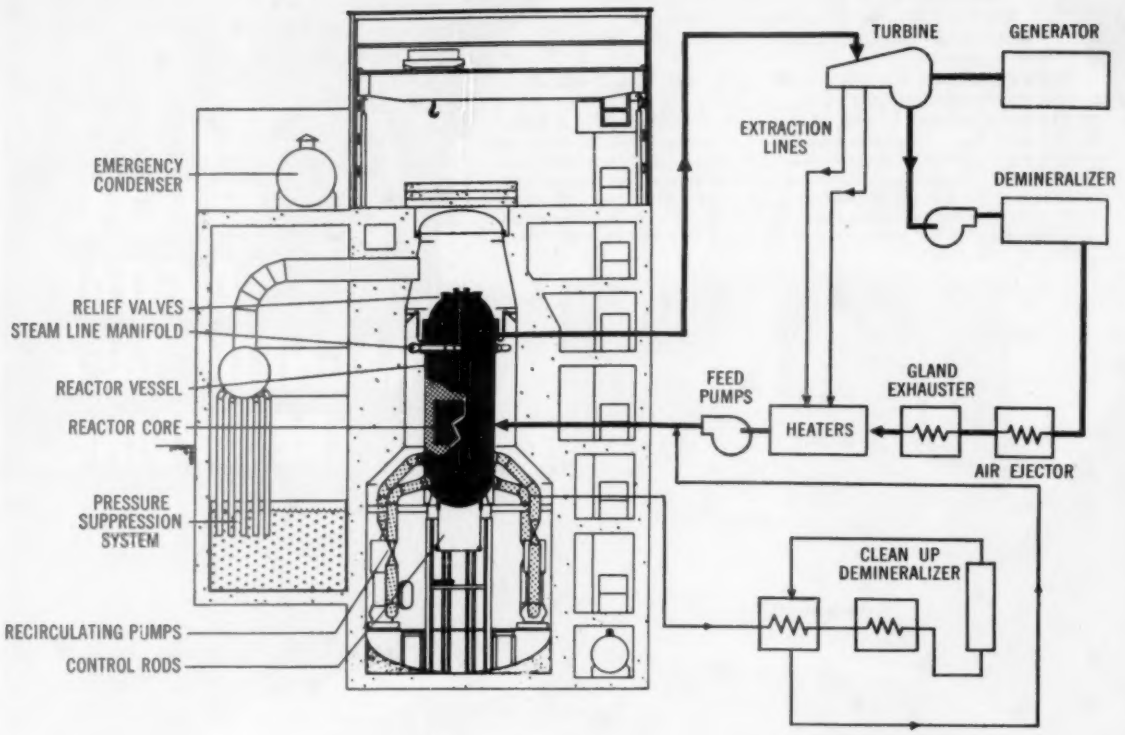
Dresden has demonstrated BWR stability, simplicity of operation and control, and ease of maintenance. Technical



General Electric
Nuclear Technology Helps
Keep Power Costs Low



Dresden—
Large Boiling
Water Reactor Feasibility
(Commonwealth Edison Co.)



COMPACT REACTOR SYSTEM arrangement and pressure suppression containment for single-cycle boiling water reactor plants reduces capital cost, simplifies construction. Pressure suppression was developed by General Electric Company in conjunction with Pacific Gas & Electric Co

development program results include pressure suppression containment, steam separation within the reactor vessel, higher core power density, and significant increases in plant rating.

Research and development work is continuing to further reduce the costs of boiling water nuclear plants—projects on fuel design, higher core power density, materials, equipment compaction, and nuclear superheat.

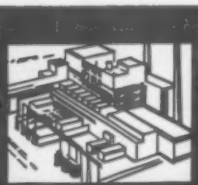
For more information on General Electric commercial atomic activities, contact your nearby G-E Sales Office or write to General Electric Company, One River Road, Schenectady, N. Y. Outside the United States and Canada, contact International General Electric Company, 150 East 42nd St., New York, N. Y. 132-11

BWR PLANT SPECIFICATIONS

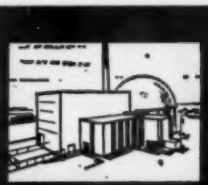
	Natural Circulation	Forced Circulation			
		Single Cycle	Single Cycle	Single Cycle	Dual Cycle
Generator Output (Mwe)	100	200	303	405	500
Net Plant Output (Mwe)	96	191	289	387	481
Reactor Thermal Power (Mwt)	330	618	935	1240	1600
Sat. Steam Pressure at Turbine (psia)	975	1035	1035	1035	[pri. .965 sec. .475
Containment System	Pres. Supp.	Pres. Supp.	Pres. Supp.	Pres. Supp.	Sphere

Progress Is Our Most Important Product

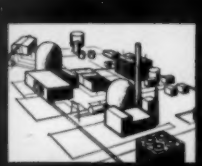
GENERAL ELECTRIC



Humboldt Bay—
Natural Circulation,
Pressure Suppression
(Pacific Gas &
Electric Co.)



Big Rock—
High Power Density
(Consumers
Power Co.)



EVESR—
Nuclear Superheat
(Empire State Atomic
Development Associates)

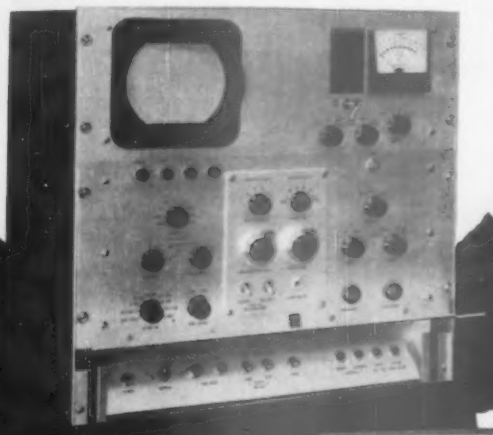
FAST! Four-second transfer from or to analyzer (400 channels)!

AUTOMATIC! Operates completely under automatic programming controls of analyzer.

RELIABLE! Computer-proven reliability of magnetic tape recording!

CONVENIENT! No tape handling of any kind. Endless tape, cartridge-contained!

20 TIMES FASTER . . . you can't beat the combination of a RIDL Multichannel Pulse Height Analyzer System—model 34-8 200 Channel or 34-12 400 Channel Analyzer with a RIDL model 52-26 Magnetic Tape Recording and Stripping Unit—for fast transfer of analyzer data to magnetic tape. This system allows rapid successive measurements to be made with only four seconds required between the ending of one run and the start of the next. This is 20 times faster than any other form of data output!



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RIDL DIGITAL MAGNETIC TAPE RECORDING SYSTEM

. . . FOR SPECTRUM STRIPPING AND AUXILLIARY DATA STORAGE!

SPECTRUM STRIPPING, PEELING OR DATA REDUCTION . . . Data stored on magnetic tape may be added to or subtracted from data stored in the analyzer. Accuracy to 3 decimal places with multipliers of 1000%, 100%, 10%, 1% or 1/10% of data on tape.

FULL ANALYZER CHANNEL CAPACITY USEFUL . . . because the analyzer memory is not required to store the addend or augend data. All 400 channels of the analyzer memory can be used for data accumulation.

NO TAPE HANDLING . . . changing references requires only changing a cartridge. No time is lost threading or reading tapes into the analyzer before starting the data reduction operation.

FINAL PERFORMANCE TEST PROVES ACCURACY. Accumulate a spectrum. Print out and write on magnetic tape. Clear memory. Read in from magnetic tape and print out again. No difference in printed data is allowed.

FOR FULL DETAILS, write to Dept. B . . .

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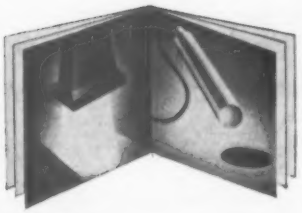


APPLIED RADIATION CASE HISTORY NO. 7

Neutron-Moderation Gages Water in Foundry Sand

If foundry sand is too dry, molds break. If it is too wet, castings have scabs and blow holes—causing rework and large scrap losses. But this production gage assures that 200 ton/hr sand has 3.4 ± 0.05% moisture

by HARVEY A. BURLEY, *General Motors Corp., Research Laboratories, Warren, Michigan*
and MILTON J. DIAMOND, *General Motors Corp., Central Foundry Div., Saginaw, Michigan*

WE HAVE CUT CASTING cleanup by 55% and reduced scrap losses at our Danville, Illinois plant by using a 2-curie Pu-Be fast-neutron source and two thermal-neutron detectors to measure the moisture in foundry sand. The more uniform sand we get with the help of this new instrument also helps us to make more complicated castings, such as crankshafts. For this new instrument we also devised a method for clearly presenting moisture data to a semi-skilled operator and a novel means of checking calibration.

Although many radiation instruments operating on this same principle have served for spot checks on agricultural, oil-well logging, road building and airport projects (*1*, *2*), application to continuous service in a production foundry imposed stricter requirements. The earlier radiation gages for measuring moisture in soil usually measured water contents of 5 to 50%, but our foundry gage functions at less than 4% moisture. Also, it is accurate to within about 0.05%, which is 20–40 times what was needed by most earlier gages. It speeds production by measuring the moisture in a 3,200-lb batch of sand and displaying the data simply to a semi-skilled operator within 45 sec. It performs these tests reliably in an equipment location where 140°F temperatures, heavy vibration, dust, dirt and falling water are routine.

Figure 1 shows how our foundry gage operates. Figure 2 and the table show the uniform moisture contents we have achieved by feeding data from the gage into a system that automatically adds the proper amount of water to the sand to maintain the desired concentration.

Unsuitable Methods

The method previously used for measuring moisture in sand involved taking a 50-gm sand sample once each

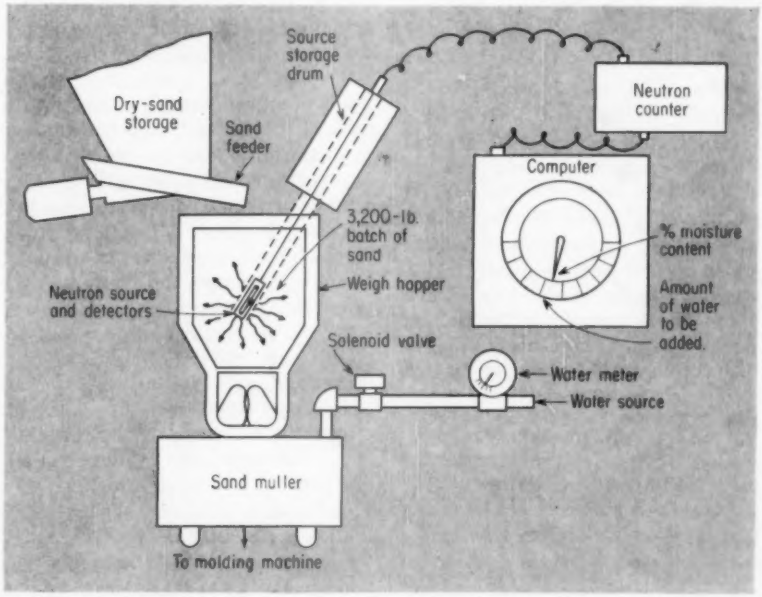
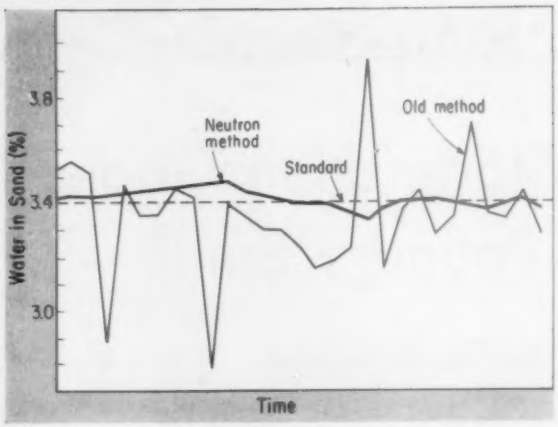


FIG. 1. TO OPERATE moisture gage 3,200-lb batch of sand feeds automatically into weigh hopper, fast neutrons from source penetrate sand, are slowed by water in sand, then slow neutrons are detected by probes next to sources. Constant-speed motor turns pointer until 100,000 neutrons are counted, then motor stops with pointer indicating water content in sand. Operator presses buttons to dump sand into muller and automatically adds needed water to sand. (Actual installation has two mullers)



Moisture-Gage Effectiveness

Samples	*Without gage*	*With gage*
Total number	92	27
No. within ±0.1%	41 (45%)	27 (100%)
No. within ±0.05%	21 (25%)	24 (89%)

FIG. 2. MORE UNIFORM amount of water in foundry sand results from use of neutron gage that measures every 3,200-lb batch (along with system that then automatically adds proper amount of water). Old method relied on slow laboratory check of 50-gm sample from every 100 tons of sand

hour and comparing the sand weight before and after drying the sample in an oven. But it took about 30 minutes to complete this measurement of a very small sample. In the meantime, our production process would handle more than 100 tons of sand. The operator literally used his sense of feel to determine how much water to add to the sand during this time. This made the process depend heavily on the experience and artistry of the operator. Inaccuracies made casting scrap losses and rework time costly.

A Better Way

In a search for better measuring methods, we considered several using electrical conductivity as a gage of moisture content. But the presence of carbon (a conductor) in varying amounts of sea coal in the sand limited these. Then we considered two other methods—one used neutron moderation by the hydrogen in the water, the other relied on the attenuation of gamma rays. Experiments showed the neutron method more promising.

Performance

Figure 2 and the table compare the old and new measuring methods. The data for these were acquired by taking two 100-gm samples from each muller batch and analyzing them by the oven-dry method. Since 200 gm out of 3,200 lb might not be a truly representative sample if the muller does not mix the sand and added water thoroughly, there is a chance that these data might not be completely accurate (but it would be impractical to oven-dry a series of 3,200-lb charges).

Other errors. The data in Fig. 2 and the table include errors due to sand fall-through, water pressure and inaccuracies in the water meter (these problems have all been eliminated since the data were taken). Fall-through error was due to additional sand that fell into the weigh lorry after the feeder stopped but while the neutron count was in progress; 200 lb of extra sand could cause ~0.3% error in the moisture reading. Errors due to the water pressure occurred when the operator could not manually turn the water feed valve off at exactly the proper point; now that water is added automatically this is not a problem. An unusual piping arrangement that we used at first to add water to the muller occasionally caused the water dial to read inaccurately.

We still have small inaccuracies due to statistical errors and errors in the computer and neutron-scaler (the computer-scaler errors add up to ~½ deg on the dial—or 0.008% moisture error). Statistically, the 100,000 counts we collect per batch result in an 0.5% error at the 90% confidence level, which in our system gives a 1.5% error on the dial (a 0.025% moisture error).

Calibration. To check gage calibration periodically the operator runs the source and detector assembly up into the shield and starts the counter. However, with the source and detector retracted in the drum, the high concentration of hydrogen in the paraffin causes a very large field of thermal neutrons. So we put a perforated cadmium tube in the inner wall of the drum to prevent most of these thermal neutrons from reaching the detectors; we adjusted the number of perforations so the neutron detectors would see a flux nearly equal to that caused by a batch of sand with 2.9% water—thus the calibration point falls at a convenient location on the indicator dial. This calibration feature also gives the operator a quick method for testing the over-all condition of the gage.

Radiation Safety

We assure safety by careful design, frequent inspections, simple operating procedures and interlocks to prevent mistakes. Alpha particles emitted from the Pu^{239} and fast neutrons are the main causes of concern. Thermal-neutron fluxes are hardly measurable and no gammas were detected by any of the 50 film badges we used during the first month of regular operation.

Alpha particles from the 32 gm of alpha-emitting Pu^{239} in the 2-curie plutonium-beryllium neutron source could be a hazard if the plutonium escapes from the source container. To prevent leakage we have a triple container. In it we have sealed the source inside a tantalum can, which is inside a weld-sealed stainless-steel container. This in turn is inside another stainless holder that is screwed shut on a compressed copper washer. Wipe tests are made every three months to detect any leakage. Even if the triple container leaks between wipe tests, any contamination would be confined within the probe itself.

Fast-neutron flux is less than the 17-

neutron/cm²/sec recommended maximum permissible dose (based on 40-hr/wk exposure of persons over 18 years old to 100 mrem/wk) (*3*) at all accessible locations even without shadow shielding. To reduce personnel exposure more, we put fast-neutron shield blocks at strategic locations around the weigh lorry. Each shield consists of paraffin sealed in a metal container ~4 in. thick × 20 × 13 in. (to keep neutrons thermalized by this paraffin from entering the sand and interfering with the moisture measurement, a 0.01-in. sheet of cadmium covers the shield surface nearest the sand). The 50 neutron film badges used during the first month of routine operation showed that the workers received less than 10 mrems for each 2-wk period, which is less than 5% of the maximum permissible exposure.

Equipment Selection

Calibration tests showed that if we are to read moisture to ±0.05%, overall system accuracy must be 1% or better. This 1% includes not only the familiar statistical error but also errors due to relays, timers, circuit nonlinearities, meters, etc. Probably the most accurate system would use a preset time scaler; the answer would appear as a number of counts and then the operator would consult a chart to learn the percentage moisture in the sand. But this arrangement would be almost unworkable under the pressure of manufacturing conditions and the operator probably soon would stop using the moisture gage. A more suitable arrangement would be to have a ratemeter with a large dial calibrated directly in percent sand moisture, but it would be almost impossible to attain the required accuracy, stability and speed of response with any conventional equipment.

So we chose a combination giving both accuracy and readability—a preset-count scaler along with a constant-speed motor that drives a large pointer on a dial calibrated in percent moisture. Tests showed that this set-up has an over-all accuracy at the 90% confidence level of better than ¼%. If the system error is ¼%, the statistical error then can be as high as ¾%. So, to provide a safety factor and make better use of the present count feature of the available scaler, we decided to use a preset count of 100,000, which gives us an error of only 0.52% with a level of confidence of 90%.

FIG. 3. PLUTONIUM-BERYLLIUM source tube is at center and two thermal-neutron tubes are just to right. Teleflex cable mounted above source housing drives assembly up or down. Source-and-detector assembly shown here (without actual source in place) has been pulled up from shield for easier viewing. Two paraffin-filled half cylinders (shown resting on top) fit into hole in upper portion of drum when the source is installed

Selecting a source. To get 100,000 counts in the less than 1 min time convenient for foundry production purposes, our source must emit 2–3 × 10^6 n/sec. In this range only Ra-Be, Po-Be and Pu-Be sources were available; we chose the Pu-Be source because of its low gamma output, long half-life and favorable operating cost. The 2-curie source we are using contains 32 gm Pu^{239} and emits 2.8 × 10^6 n/sec at an average of 3–5 Mev (10.6 Mev maximum).

Selecting detector. Because of its sensitivity, for detecting the thermal neutrons we chose a BF_3 proportional counter over fission counters, ion chambers, neutron thermopiles or solid-state devices (*4*). We selected a Westinghouse WL-6307 BF_3 tube because it was the correct size and because it had passed military tests for shock and vibration. We doubled sensitivity by using two of these tubes in parallel.

Locating gage. We first tried placing the fast-neutron source and thermal-neutron detectors in the sand within a large storage bin. But the large amount of sand in the bin compressed various parts of the sand pile differently, causing inaccuracies in gage readings. Other tests showed that the gage moisture readings are affected by only the 20 in. of sand nearest the source and detector. So we lowered the probe into a lorry in which 3,200-lb batches of sand are weighed before they are dropped into mullers that mix the sand with water and other additives.

* * *

We wish to thank particularly Robert Kinsey, Joseph Athutis and Kenneth Spray of our Danville plant and Alexander Somerville, John Danforth, Arthur Block, Alexander Meduvsky, Robert Black and Albert Stube of our research laboratory for their help.

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AEC's New Price Scale for Uranium		
Weight percent U^{235}	Base charge ($/kg U) New	Old
Enriched Uranium		
0.75	26.70	44.00
0.80	31.10	50.00
0.85	35.60	56.25
0.90	40.30	62.75
0.95	45.00	69.00
1.00	49.90	75.75
1.1	59.90	89.00
1.2	70.20	103.00
1.3	80.80	117.00
1.4	91.60	131.25
1.5	102.60	145.50
1.6	113.80	
1.7	125.20	
1.8	136.60	
1.9	148.20	
2.0	160.00	220.00
2.2	183.60	
2.4	207.60	
2.6	232.00	
2.8	256.40	
3.0	281.20	375.50
3.2	306.00	
3.4	331.00	
3.6	356.20	
3.8	381.60	
4.0	407.00	535.50
4.5	471.00	616.50
5.0	535.50	698.25
5.5	600.50	780.25
6.0	665.50	862.50
7	797.00	1,028.00
8	929.00	1,195.00
9	1,062.00	1,362.00
10	1,195.50	1,529.00
12	1,464.00	
14	1,733.00	
16	2,004.00	
18	2,275.00	
20	2,547.00	3,223.00
25	3,230.00	4,078.00
30	3,915.00	4,931.00
35	4,602.00	5,793.00
40	5,292.00	6,654.00
50	6,676.00	8,379.00
60	8,066.00	10,111.00
70	9,462.00	11,850.00
80	10,865.00	13,596.00
85	11,575.00	14,475.00
90	12,285.00	15,361.00
92	12,575.00	
94	12,865.00	
95	13,015.00	16,258.00
Depleted Uranium		
0.22	3.00	5.00
0.40	3.00	8.15
0.42	3.75	
0.44	4.70	
0.46	5.75	
0.48	6.85	
0.50	8.05	16.65
0.52	9.30	18.65
0.54	10.60	20.65
0.56	11.95	22.65
0.58	13.35	24.75
0.60	14.80	26.90
0.65	18.60	32.50
0.70	22.60	38.15

AEC's New Prices How Will They

The recent 20–34% cut in uranium prices in spite of the accompanying increase in slightly-enriched-uranium cycles than

by DAVID P. HERRON, *American Radiator & Standard*

AEC's NEW PRICE SCALE for enriched uranium (see left) and new 4.75% per annum use charge (*1*) will mean a ¼-mill/kwh saving for natural-uranium reactors and twice this for slightly-enriched-uranium reactors. The latter benefit more from the new prices than the natural uranium reactors because they derive a smaller fraction of their power output from plutonium burnup. Should the AEC decide, however, to reduce its buyback price for plutonium in proportion to the price changes for uranium, the net savings for enriched reactors (which normally include a plutonium credit in their fuel-cycle costs) would be more nearly equal to that for natural uranium reactors.

Reduced ore price. The new price scale is based on a price for uranium ore concentrates of $8.00/lb U_3O_8, which is at or slightly above the current world uranium market price. The former price scale was based on ore concentrates at about $14.00/lb U_3O_8. In its announcement the AEC stated that the new price scale did not reflect a change in diffusion-plant costs; hence presumably the unit cost of separative work remains at $37.29/kg uranium in calculations of the new price scale (*2*).

Rather paradoxically the reduction in ore price, combined with the new rate of inventory charges, in most instances reduces the power costs for slightly enriched reactors more than for natural-uranium reactors. To demonstrate this let us calculate B the burnup cost per gram of U^{235} consumed from the equation (*3*)

$$B = \frac{1}{1{,}000}\left[\frac{C_F + C_S(V_W - V_F)}{X_P - X_W} + C_S\frac{V_P - V_D}{X_P - X_D}\right] \quad (1)$$

(C is unit cost in $/kg of contained uranium; V is the value function given by $(1 - 2X)\ \ln[(1 - X)/X]$, and X is weight fraction U^{235}. Subscript D refers to uranium discharged from the reactor, F to natural-uranium hexafluoride fed to the diffusion plant, P to the uranium fuel fed to the reactor, S to unit separative work in the diffusion plant, and W to the diffusion-plant bottom discharge (tails) at the concentration that gives minimum product cost.)

The burnup cost m in mills/kwh is

$$n = \frac{BY}{24\eta_t} \quad (2)$$

where Y is the amount of U^{235} consumed or unrecoverable per megawatt-day of heat released and η_t is the overall plant thermal efficiency.

For a reactor operating with given feed and discharge enrichments, the change in fuel-cycle cost resulting from the new uranium price scale is

$$\Delta m = \frac{Y \times 10^{-3}}{24\eta_t}\,\Delta\left[\frac{C_F + C_S(V_W - V_F)}{X_F - X_W}\right] \quad (3)$$

In Eq. 3 the Δ term on the right is independent of the reactor feed and discharge concentrations. Hence the re-

for Uranium . . . Affect Power Costs?

means a ¼–½-mill/kwh bonus in fuel-cycle cost, use charge to 4.75%. The saving is greater for for cycles that use natural uranium fuel

Sanitary Corp., Mountain View, California

actor types with higher values of Y (gm U^{235} consumed per Mwd of heat) will benefit more from the new price scale. Slightly enriched reactors generally have higher values of Y than do natural-uranium reactors.

The prices published in the old and new price scales appear to be based upon the following values for C_F, C_S, and X_W

	Old scale	*New scale*
C_F ($/kg)	39.27	24.00
C_S ($/kg)	37.29	37.29
X_W (w/o U^{235})	0.221	0.275

Putting these numbers into Eq. 3 we get

$$\Delta m = \frac{0.138Y}{\eta_t} \qquad (4)$$

Equation 4 allows us to compare the change in fuel-cycle cost for a slightly enriched reactor with that for the "throwaway" fuel cycle of a natural-uranium reactor. In Table 1 we see that the last line shows the saving in burnup cost for the slightly enriched reactor is about 0.23 mills/kwh greater than for the natural-uranium reactor.

TABLE 1—Burnup-Cost Saving

	Slightly enriched	*Natural-uranium*
Exposure level (Mwd/tonne)	12,000	10,000
η_t	0.30	0.30
Initial w/o U^{235}	3.00	0.7115
Final w/o U^{235}	1.889	(discarded)
Y (gm U^{235}/Mwd)	0.958	—
Δm (mills/kwh)	0.44	0.21

Effect of higher use charge. The AEC has published typical inventory charges for large slightly enriched reactors and for natural-uranium reactors based on 4% interest rate (4); we can recalculate these as shown in Table 2 for a 4.75% interest rate based on the new price scale.

The inventory cost shows the greatest decrease for the slightly enriched fuel cycle with stainless-steel cladding and the least decrease for the natural-uranium cycle.

Combining the changes due to ore price and use charge we obtain

Total reduction in power cost (mill/kwh)	
Slightly enriched, stainless-steel cladding	0.49
Slightly enriched, zircaloy cladding	0.46
Natural-uranium, throwaway cycle	0.22

Effect of plutonium credit. The $12/gm credit offered for plutonium by the AEC remains in effect through June 30, 1963. The AEC, however, has not committed itself beyond this 1963 date and states: "If the estimated fuel values of plutonium and U^{233} [now $12/gm and $15/gm, respectively] were related to the revised charges for enriched uranium by the method used previously, they would be reduced by about 20%." Plutonium credit for slightly enriched reactors is in the neighborhood of 0.75–1.0 mills/kwh; hence a 20% reduction would mean an increase in fuel-cycle cost of roughly 0.15–0.20 mills/kwh. This increase does not occur in the throwaway cycle of the natural-uranium reactor.

TABLE 2—Effect of New Use Charge on Inventory Cost (mill/kwh)

	Old use charge (4%), old price scale	*New use charge (4.75%), new price scale*	*Cost difference*
Slightly enriched water reactor			
Stainless-steel cladding	0.49	0.44	.05
Zircaloy cladding	0.15	0.13	.02
Natural-uranium reactor	0.05	0.04	.01

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Modifying EBWR Vessel for 100-Mw(th) Operation

To install larger nozzles on the reactor vessel, we removed the fuel and control rods, then used lead and water shielding to limit working radiation level to only 15 mr/hr. We finished the changes within 55 days

by JOSEPH M. HARRER and THOMAS L. KETTLES, *Argonne National Laboratory, Argonne, Illinois*

UPRATING the Experimental Boiling Water Reactor from 20 to100 Mw(th) meant that we had to install larger (10 in. and 6 in.) nozzles and make other changes to the upper part of the reactor pressure vessel. On a previous occasion we had installed some small nozzles in the closure-ring forging, so we knew this type of work could be done even with the fully loaded radioactive core in place. However, ordinarily neither 10-in. nor 6-in. nozzles are added to any type of pressure vessel in the field. But radioactivity prevented us from removing the vessel for repairs in a shop. Since we wanted to minimize both radiation exposure to our workers and the time to do the work, we planned and developed our procedures carefully in advance, then removed the fuel and control rods from the vessel so we could lower the water in the vessel and work on the vessel wall directly.

Speed and safety. By first developing procedures and training machinists and welders in our shop with a "cold" mockup consisting of a 4 × 8-ft curved section of clad plate (and by working a 24-hr day 7 days per week) we finished the vessel modifications in just 55 days. Health physicists monitored all work to assure that no workman received more than 300 mr/wk or 100 mr in any one day. We wore air breathing masks at the start of each new machining, torch-cutting, welding, grinding and cleanup operation. Highest airborne activity was found when we sanded the vessel during final cleanup—it was 20% of the permissible β-γ dose rate for Co^{60} at the sander and 5% just outside the vessel (we used limits for unknown isotopes until analysis showed most of the β-γ activity during all operations was due to Co^{58} and Co^{60}); activity at both places was less than the permissible value for unknown isotopes.

Step by Step

We had to remove the old pipe outside the vessel, then go inside the vessel to take out the upper shock shield, the 6-in. steam outlet with its dry-pipe collection ring and the upper shock shield. Then we added a 10-in. steam outlet with its steam-collection duct, a 6-in. feedwater inlet, two 1½-in. connections for measuring water level, three 2-in. connections for instrumentation, three 1-in. connections for blowdown and a new shock shield.

Removing fuel, control rods. To reduce the radiation level within the vessel, we first removed the fuel and control rods from the water-filled core. It took about 15 minutes to lift (singly) each of the 112 fuel assemblies and 36 dummies into a lead-lined transfer cask, roll the cask over a nearby water-filled storage pit and lower the fuel ele-

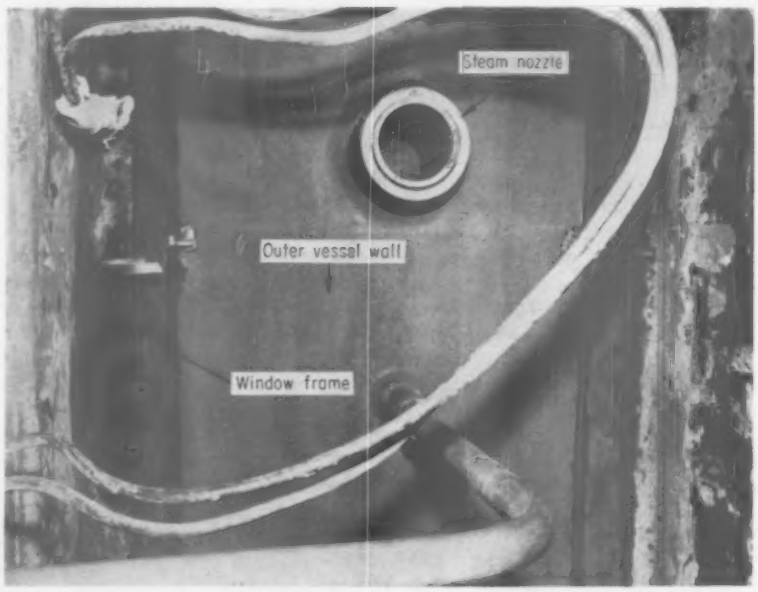


FIG. 1. ACCESS TO OUTER wall of reactor vessel was gained by removing shield blocks in upper pipe tunnel through shield. Then we removed 430ss wire mesh and wool thermal insulation, sealed annulus between vessel and steel cylinder with sheet-metal "window frame" and sawed through steam nozzle so we could remove steam dry-pipe ring from inside vessel. Highest background in tunnel was 10 mr/hr when vessel was full of water, but rose to 30 mr/hr after we lowered water to top of thermal shield

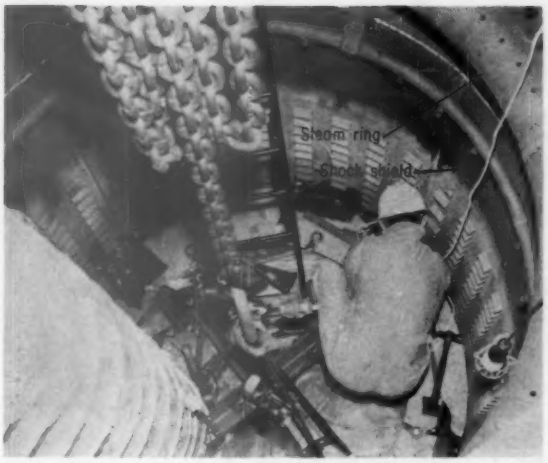


FIG. 2. TO REMOVE four lower 6.7-ft lengths of shock shield, we sheared off $\frac{1}{2}$-in. cap screws and nuts holding sections to each other and to thermal shield (we retained maximum shielding by lowering water and platform in increments as needed to uncover next lower screws). Note the dark zone that begins ~3 ft above operating water level

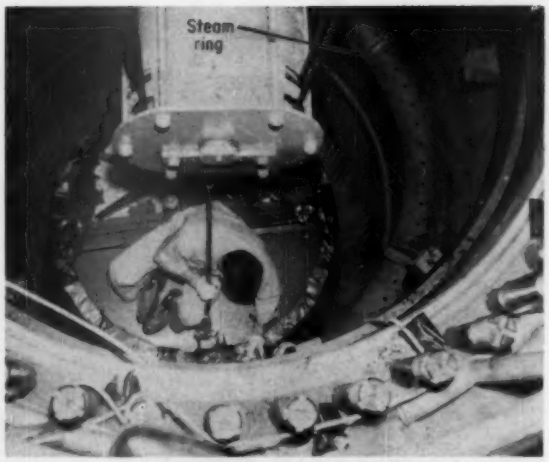
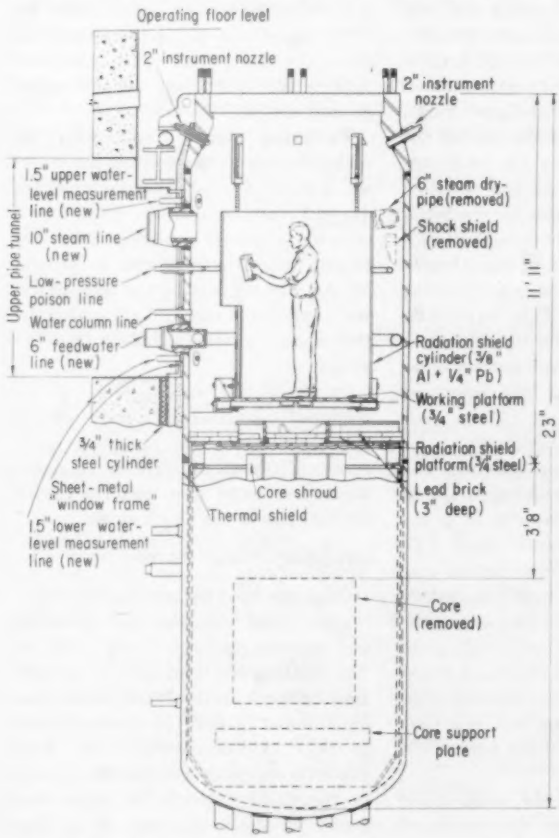


FIG. 3. RADIATION SURVEY of vessel showed that removing shock shield lowered 1,000-mr/hr background 6 in. above core shroud to 850 mr/hr (highest intensity 2 in. from vessel wall was 1,000 mr/hr). After we washed wall six times, background 6 in. above core dropped to 650 mr/hr (wall activity dropped 10–20%). Note scalloped light and dark zones on wall

FIG. 4 (below). TO SHIELD WORKERS from radiation from core shroud and lower vessel, we placed lead bricks on platform atop thermal shield; then with water level 2 in. above core shroud, background 3 ft above bricks was 35 mr/hr, 2 in. from vessel wall activity was 80 mr/hr. For first work, on upper water-level-measurement nozzle hole, we raised water level and working platform (on which we rested shield cylinder to reduce dose from wall) to convenient working height; then we lowered water level and working platform as needed to work on each hole on down until we got to lowest hole



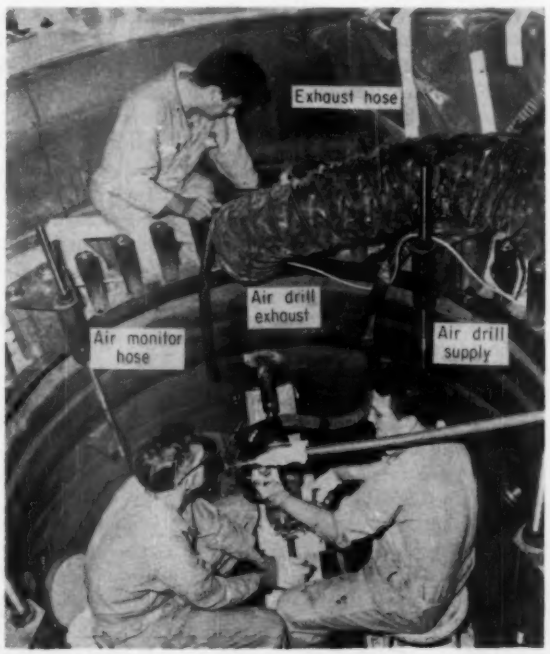


FIG. 5. DRILLING hole in closure-ring forging for one of the three 2-in. instrument nozzles. The reactor vessel itself was designed for 800 psi at 650°F temperature; its inside diameter is 7 ft. The vessel wall is made of $2\frac{7}{16}$-in. SA-212 Grade B carbon steel; it is clad on the inside with 0.109-in. Type-304 stainless-steel sheet spotwelded to the carbon steel

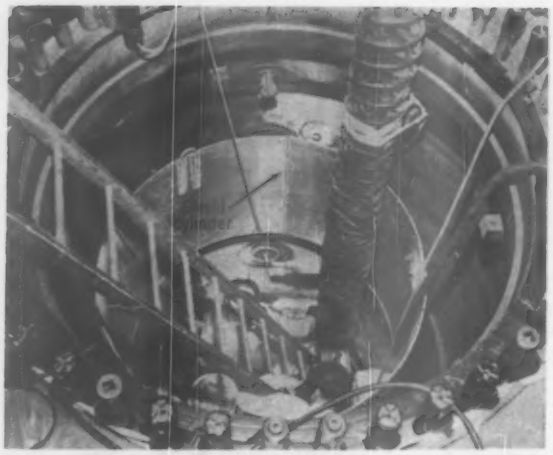


FIG. 7 (above). WELDING 6-in. feedwater nozzle to vessel shell using E-7015 electrodes to fill groove

FIG. 6 (left). MECHANIC PREPARING to preheat steam nozzle and vessel before welding nozzle, liner and pipe

ment into a boron-stainless-steel rack at the pit bottom. Highest background during transfer was 200 mr/hr.

The 10 × 10-in. × 15-ft cruciform control rods were too long to transfer in the same way until we cut them into 5-ft pieces using an underwater saw. It took six 8-hr shifts to cut and transfer all nine control rods. Maximum background during transfer was 50 mr/hr.

Removing old pipe. To take out the old pipe and gain access to the outer wall of the reactor vessel, we took the concrete shield blocks from the upper pipe tunnel in the 8-ft-thick concrete shield, removed ¼ in. of ferroboron plaster, 2 in. of lead shield and two 6 × 3.5-ft pieces cut from the ¾-in. carbon-steel cylinder that forms the inner surface of the shield (as shown in Fig. 1).

Removing shock shield. We gained access to the vessel inner wall by removing the 6.5-ft-diameter shock shield (Fig. 2) that lined the vessel from the steam dry-pipe ring down 7.5 ft, where it bolted to the top of the thermal shield; the shock shield consisted of four ⅛-in. curved sheets of 304ss bolted together.

This work was difficult because the shock shield was quite radioactive. When the water was level with the top of the thermal shield, radiation intensity was 75 mr/hr at the vessel top and an average of 1,000 mr/hr 2 in. from the shock-shield inner surface. In an effort to remove radioactive deposits we scrubbed exposed surfaces with wet rags. Four washings reduced activity an average of 10% on vertical surfaces and 67% on horizontal surfaces (such as atop the steam dry-pipe ring). Activity near the core shroud did not drop immediately after the washings, but it did after about two days (by then the radioactive particles in the wash water had settled to the vessel bottom).

The dark zone shown in Fig. 2 begins about 3 ft above the water level during reactor operation. This darkening might have been caused by differences in the action of the steam and water on the stainless steel at the interface. The dark zone did not lighten even when we scrubbed it vigorously.

The men doing the washing and working on the shock shield stood on a bucket platform lowered into the vessel by the overhead crane. To minimize exposure to radiation, we raised the water level to 2 ft below the top of the shock shield so men on the bucket platform could chip and grind off the upper 10 in. of the shock shield to get it from behind the steam dry-pipe ring. Figure 2 shows how we then unfastened the lower 6.7-ft part of the shock shield.

When we removed the shock-shield sections from the vessel, they measured a maximum 1,250 mr/hr at 2 in. We cleaned one section in a tank with various chemicals for two days, but this reduced activity only negligibly. So we dropped our plans to rework the shock-shield sections to fit the new nozzles and sent them to the burial ground instead.

Removing steam ring. After we sealed the bucket platform to the vessel wall 2 ft below the 6-in.-diameter steam dry-pipe ring (shown in Figs. 2 and 3 near top of vessel) and raised the water to just under the platform, we ground off the lugs supporting the ring on the wall, sawed the ring in half, sealed the two pieces and removed them from the vessel.

In Fig. 3 the bottom points of the scalloped light and dark zones on the vessel wall are at the operating water level. The pattern might be due to the steam and water flow patterns caused by the slots in the shock shield.

Installing New Parts

We completed the renovations to the reactor vessel using the shield platform and working platform shown in Fig. 4. The working platform is shown in position for work on the lowest hole—that for the new lower 1½-in. water-level nozzle. At this position, the work platform rested on lead shielding bricks on the shield platform, the water level was 2 in. above the core shroud, and

workers were exposed to the highest working radiation background experienced during the modification work—15 mr/hr.

After chipping away the spot-welded vessel cladding, for the steam and feedwater nozzles we cut 16⅝-in. and 11⅝-in. holes with an oxyacetylene torch and finish-ground the holes to get 10-deg side taper. It took us 6½ days to prepare all the holes, including drilling a hole for an extra 2-in. instrument nozzle in the closure-ring forging shown in Fig. 5.

We installed a stainless-steel diaphragm plate for each nozzle. Nozzles were of carbon-steel SA-105 Grade-II bar or SA-106C hollow-rounds. We welded the nozzles to the vessel using E-7015 electrodes and stress-relief peened each weld layer; gas heat preheated and held 300°F interpass temperature. All the new nozzles are of carbon steel lined (but not bonded) with stainless steel. Before welding the nozzles to the vessel, we x-rayed, hydrostatically tested and leaktested them with helium. To allow differential expansion with minimum restraint, we welded the stainless liner to the outer ends of the nozzle and to the diaphragm plate welded to the vessel cladding.

Figures 6 and 7 show the feedwater and steam nozzles being welded into place.

To show that all carbon-steel nozzle welds are sound and defect-free, we radiographed them with a 13-curie iridium source. We also leakchecked (with 200–600-psi nitrogen) the diaphragm welds of nozzles that have monitor connections. Then we removed the shield cylinder, lowered the feedwater distribution ring (in halves, as we had removed the old steam drypipe ring) into the vessel, and welded the feedwater nozzle and the ring support lugs to the inside of the vessel to complete the installation. (To provide a continuing check on leaks we monitor the clad:base-metal space on the steam, feedwater and instrument nozzles via ¼-in. pipes that pass out through the shield.)

Closing upper pipe tunnel. We arc-welded pipes from the new nozzles to terminals outside the reactor shell. But first we matched the ends of the pipes and fittings before we assembled them and used fixtures and supports to assure close alignment. We used consumable rings and shielded tungsten-arc methods for the root passes; helium served as the blanketing gas within the pipes during welding to exclude air from the weld. To reduce the amount of helium we used, we blew up rubber gloves and toy balloons to fit tightly within the pipes.

By using careful assembly sequence and mirror arrangements we observed 95% of the backs of the welds. We used dye penetrant to inspect root passes from the front side of the welds. All joints that had not been x-rayed in the shop were radiographed with a 7-curie iridium source.

We ground the pipe welds outside the shield to 3/32-in. maximum reinforcement and examined them with dye penetrant but did not radiograph them.

Before we refilled the pipe tunnel with shielding materials, we removed the window frame, fastened the 430ss-wool thermal insulation to the vessel wall, bolted in place the two ¾-in. steel-plate sections, formed the ⅝-in. copper tubes to fit the new nozzle arrangement, annealed and hydrostatically tested them, poured molten lead against the steel plates and around the copper tubes, insulated nozzles and pipes with 430ss wool, fastened extruded metal lath to the galvanized sheet-metal forms that had been used for pouring the lead, troweled the lath ½-in. thick with ferroboron plaster and placed steel troughs around the pipes to protect the insulation. Then we laid the concrete shielding blocks and covered the filled tunnel with a steel plate.

After hydrostatically testing the vessel, nozzles and piping at 1,200 psi, we completed the water-level-measurement piping and terminated the steam and feedwater pipes for continuation by the plant-piping contractor.

After all modifications were completed, we drained the reactor vessel and found that activity at the top of the vessel measured 15 r/hr. This indicates that we will face a major challenge when the day comes for us to inspect or modify parts below the top of the core shroud.

* * *

Over 70 persons helped revise the EBWR reactor pressure vessel. N. Balai provided many answers to nozzle-design and welding problems. O. W. Flood, L. F. Franck, F. A. Simon, A. D. Paulsen, M. A. Duhatschek, E. F. Lewandowski, A. H. Lundin, L. S. Lachnowicz, et al. of the laboratory shops fabricated and installed parts in the vessel; they also built and tested special tools. G. L. Skinkle and R. D. Wylie of Babcock & Wilcox Co. provided materials and technical information; they were particularly helpful in rushing to the job special welding electrodes when they were sorely needed.

EBWR CORE

OLD	vs	NEW
POWER		
20 Mw(th), 5 Mw(e)		100 Mw(th), 5 Mw(e)
CORE		
4 × 4-ft vertical cylindrical consisting of 112 assemblies, each with 6 Zr-2-clad plates containing 1.4%-enriched U in Zr-2 (average burnup now 0.2%)		5 × 4-ft vertical cylinder using original core elements plus 32 new assemblies (spikes) each with 815 gm U^{235} in a UO_2-ZrO_2 mixture in Zr tubing 4 ft high; 49 rods/assembly
CONTROL-ROD DRIVES		
9-lead-screw-and-nut mechanisms driving rods through linear seals, 4-ft stroke		9 rack-and-pinion mechanisms in thimbles; drive is through rotary seals, 5-ft stroke
CRUCIFORM CONTROL RODS		
5 hafnium rods 4 ft high with Zr-2 followers; 4 boron-steel rods 4 ft high with Zr-2 followers		9 absorber rods of 2 w/o B in 304ss 5 ft high, with unfueled Zr-2 followers (these are now replacing fueled cermet followers, which were unsatisfactory)

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Irradiated Polyethylene Comes of Age

The superior properties of the irradiated material—high-temperature performance, stress-cracking resistance and a unique shrink-fitting capability—have spurred the commercial production of irradiated polyethylene

by ROBERT A. WARD, *General Electric Co., Schenectady, New York*

IRRADIATION PROCESSING of polyethylene to improve its properties for industrial and consumer applications is by now a commercial reality. Although ordinary polyethylene is in its own right an extremely useful material, its melting point is low—just above the boiling point of water (even the newest high-density versions melt below 125°C). Treatment of polyethylene with high-energy radiation produces a material that does not melt and flow but retains its integrity up to its thermal-decomposition temperature of 250°C (see Fig. 1a). Moreover irradiated polyethylene, unlike most available polyethylene materials, has no tendency toward environmental stress cracking (see Fig. 1b). These added advantages (see Table 1) herald a growing market for the irradiated material (already ~2 million pounds in 1961) to supplant ordinary polyethylene in present-day uses and to fill entirely new ones. Two of the best known current applications are as a dielectric material in the electric industry and, more recently, as a food-wrap and packaging material (NU, May '60, p. 122). Both of these uses take advantage of still another unique property of irradiated polyethylene—with proper work and heat treatment a film of the material will shrink to form a tight, void-free sheath about any object that it encloses (see Fig. 2).

Irradiated polyethylene is being produced commercially by bombarding the polymer with high-energy electrons from resonant-transformer electron generators.

Although a commercial electron-beam facility represents a considerable investment for large volume production, it is economically competitive with other methods if maximum utilization of the electrons is obtained.

Irradiated polyethylene was introduced commercially in 1954 as tape and film for electrical insulation under General Electric's trademark "Irrathene."* Today irradiated polyethylene is marketed in many forms for several applications. A few of them are: Irrathene tape and film by the General Electric Co., Cryovac films for food wrapping by the W. R. Grace Co., and extruded parts and wire coatings by the Raychem Corp. and Radiation Materials Inc.; Sequoia Division of Anaconda Wire and Cable, Suprenant, and Radiation Dynamics are also active in the irradiated-wire field.

* A patent covering the electron-irradiation of plastics was recently awarded to Electronized Chemicals Corp. (see p. 31 this issue; also NU Wk, 29 June '61, p. 1).

Beneficial Effects

Just what does irradiation do to a polymer that has a beneficial effect? The answer is that radiation induces crosslinking—the original mixture of single discreet molecules becomes a continuous network, each individual molecule tied to many others through crosslinks. At room temperature, the

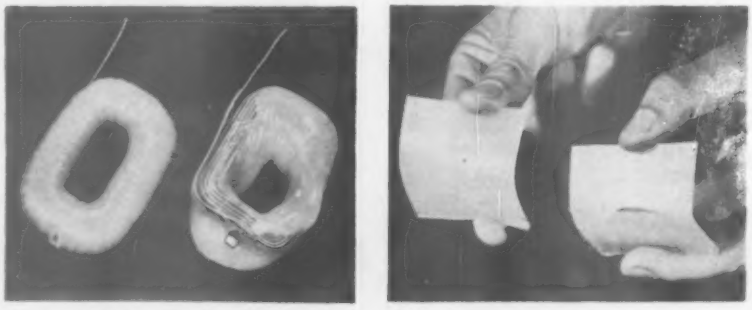

FIG. 1. IRRADIATED POLYETHYLENE does not (left) melt even at high temperatures (250°C) or (right) develop stress cracks in unfavorable chemical environment. Unirradiated polyethylene (right-hand samples) has both these disadvantages

TABLE 1—Irradiation-Induced Changes in Polyethylene

	Low-density material		*High-density material*	
	Not irradiated	*Irradiated*	*Not irradiated*	*Irradiated*
Specific gravity	0.91–0.93	0.91–0.93	0.94–0.96	0.94–0.96
Tensile strength (psi) 77°F	1,500–2,000	1,500–2,000	2,800–6,400	2,800–6,400
230°F	0	100	500	1,400
Elongation (%) 77°F	200–550	200–550	25–500	25–500
230°F	0	1,000	500	1,500
Melting point (°F)	212–230	none	257–275	none
Transparency	Clear	Clear	Translucent	Clear
Stress cracks	Yes	No	Yes	No

irradiated crosslinked polyethylene has the same toughness and flexibility as ordinary polyethylene. However, regular polyethylene melts at 105–135°C to form a viscous liquid that flows even under zero load. The crosslinked material does not melt in this way (see Fig. 1a).

Instead it loses strength about linearly with temperatures up to the melting point of normal polyethylene and at this point levels off as a rubbery material with 10–20% of its room-temperature strength and remains virtually unchanged up to its thermal decomposition point above 250°C. Figure 3 shows the stress-strain relationship at elevated temperatures for low-density polyethylene irradiated to a 15 megarad dose.

The irradiation needed to produce adequate crosslinking depends on the intended use of the polyethylene. Table 2 lists the doses required to achieve certain properties in a typical pure high-pressure low-density polymer.

The ability of the irradiated polymer to maintain integrity at high temperatures and not drip or flow has opened up a unique use for crosslinked polyethylene as a packaging material. Orientation or stretching of the irradiated material (by cold drawing, for instance) markedly increases the tensile strength, reduces the ultimate elongation and significantly improves clarity or transparency. When the oriented material is heated above the orientation temperature the stresses built in during the working process cause the material to relax and shrink to its original condition. Hence an envelope of the stretched irradiated material will, when heated, contract to form a skin-tight package about the article contained within (see Fig. 2).

FIG. 2. ADDED ADVANTAGE of irradiated polymer is tendency to shrink on heating to fit contours of enclosed article

Table 2 shows typical data for an irradiated extruded low-density polyethylene film stretched after irradiation and then relaxed or shrunk at 150°C.

Figure 4 shows the tensile force generated by the shrinking process as the sample is heated up. The force reaches a maximum at 90–100°C and then, as the crystallites disappear, drops off to essentially zero at 125°C. On cooling, the stress begins to build up again as crystallization takes place within the polymer. At room temperature, the film develops considerable tension if it is restrained from shrinking all the way. When an object is wrapped and encapsulated by heating, this force compresses the film about the object giving a tight seal. Heating to 135°C or above will heat-seal irradiated low-density polyethylene to itself. The advantages inherent in this material for packaging, wrapping and easy formation of void-free encapsulations are manifold.

The other outstanding property of irradiated polyethylene is its resistance to environmental stress cracking. (In stress cracking, surface-active agents cause cracking at stress points in the polymer.) Under severe conditions, cracks can propagate completely through the material (Fig. 1b). This common failure of unirradiated polyethylenes is eliminated by the radiation-induced crosslinking process. The best unirradiated resins last only about ½ to 10 hr in standard stress-cracking tests (time to 50% failure in glacial acetic acid at 50°C). All of our irradiated specimens of high-pressure, low-density polyethylene have survived the glacial-acetic-acid test without failure for over 2,000 hr at 75°C and for over a year at 25°C.

Radiation Source

The electron beam is the one radiation source that offers many advantages for irradiating polyethylene with no severe disadvantages. With this process polyethylene can be crosslinked without additives, even in the presence of fillers and antioxidants, and the irradiated materials are nontoxic. Operating an electron beam generator is a simple procedure requiring no special skills or aptitudes; any alert technician can be trained for all phases of the job in about a week. The current available high-voltage electron beams have removed previous limitations on the thickness of the irradiated article. A 4-Mev generator, for example, can uniformly irradiate up to 1-in. thickness of polyethylene. In addition, the electron beam is well suited for continuous round-the-clock processing. Unlike most chemical processing, it is an instant stop-go operation capable of precise control. Open the shutter and the beam starts irradiating the material, close the shutter and all reaction stops.

On the other hand the electron beam is only one of many sources of irradiation and, further, irradiation is not the only method available for crosslinking polyethylene. Peroxides are efficient

TABLE 2—Doses to Low-Density Polyethylene

Property desired	*Minimum radiation dose (megarads)*
Stress-crack resistance	1–2
Form stability	3–4
Optimum balance of properties	15–20

crosslinking agents (*6, 7*) and combinations of peroxides and vulcanizing agents common to the rubber industry are finding favor in some specific applications. However, to be effective, these curing agents must be added to and intimately combined with the polymer and this immediately suggests a possible liability. The additives in use today, or their residues, can migrate out of the polymer and cause contamination corrosion and electrically conductive surfaces. This disadvantage may rule out chemically crosslinked materials for food packaging and limit their use as electrical insulation. From the process point of view, chemical curing also presents a practical problem. The vulcanizing or crosslinking agents must be thermally activated by heating at temperatures considerably above the melting point of polyethylene; hence, the polyethylene must be held in shape as a viscous liquid before the crosslinking process begins. Unless the polymer is reinforced or contained in a mold, close tolerances cannot be maintained. Production of free film by this process, for example, is not practical.

Radiation from isotope sources and artificial ultraviolet light also produce crosslinking in polyethylene (*8*). With these sources one uses "sensitizers" swollen into the polymer which decompose under irradiation to enhance the formation of radicals and crosslinking. Here again the need for extraneous materials and the process for putting them into the polymer limit usefulness. The relatively small penetration range of the ultraviolet light and the inhibition of this type of radiation by pigments and ultraviolet absorbent (needed for outdoor weathering resistance of the irradiated product) are further limitations.

The electron-beam process does, however, require large-volume production to be economical because of the initial cost of the generator equipment and facilities to house the equipment and to shield personnel. Actual costs

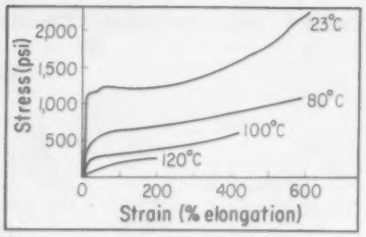

FIG. 3. STRESS vs. STRAIN as a function of temperature in 10-mil Irrathene film. Polymer was irradiated to 15 megarad

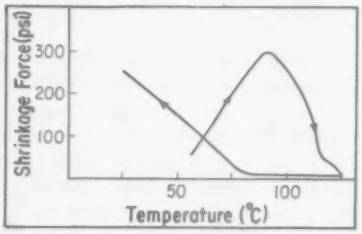

FIG. 4. SHRINKAGE FORCE vs. temperature in irradiated low-density polyethylene. Polymer is in state of tension on cooling

How Radiation Brings About Changes in Molecular Structure of Polyethylene

Exactly how does high-energy radiation act on the polymer to form crosslinks? The thinking on this question (1–4) can be summarized as follows: Interactions of the incident radiation with the polymer produce free radicals randomly distributed throughout the material. These radicals are simply polymer chains that have lost a hydrogen atom. (Such radical pairs are formed when a free hydrogen atom abstracts a hydrogen atom from an adjacent polymer chain or when a radiation event removes two hydrogens.) Two neighboring radicals (see Fig. 5) combine or crosslink at the vacated sites provided they are capable of a certain minimum amount of movement. Two adjacent hydrogen atoms lost from the same molecule can result in an intramolecular bond formation or trans-unsaturation. Minor amounts of main-carbon-chain scission can also take place.

Since crosslinking between molecules occurs only in amorphorus (noncrystalline) regions of the polymer where the radicals have the required mobility, one would expect that the radiation response of various polyethylene polymers is highly dependent on the state of crystallization; the amount of branching and the temperature of irradiation.

Detailed studies (5) of the effect of physical state, (the degree of crystallinity and temperature of irradiation) on the crosslinking efficiency of polyethylene confirm this expectation. Figure 6 shows the percentage of nonlinking (fraction of material insoluble in boiling toluene) plotted against the irradiation dose for a typical crystalline high density polyethylene. Irradiation at room temperature in the crystalline state shows poor response to the irradiation compared to the response at 150°C where the polymer is completely amorphous. Since the same radiation dose should form the same number of radicals at both temperatures the question arises as to what becomes of the great number of radicals not consumed in the crosslinking at the low-temperature irradiation. These radicals remain trapped as active agents in the crystalline regions of the polymer ready to combine with atmospheric oxygen and degrade the polymer through chain scission and embrittlement. To avoid these effects the radicals must be removed by annealing or by treatment with chemical additives.

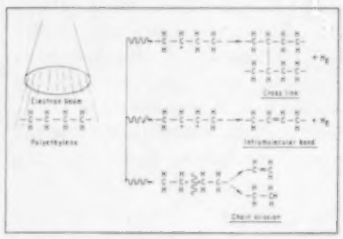

FIG. 5. EFFECT OF RADIATION on polymer results in cross linking, intramolecular bonds and scission

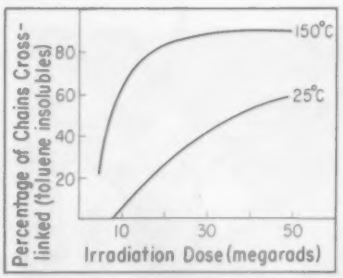

FIG. 6. CROSSLINKING vs. irradiation dose for high density polyethylene irradiated in crystalline (25°C) and amorphous (150°C) states

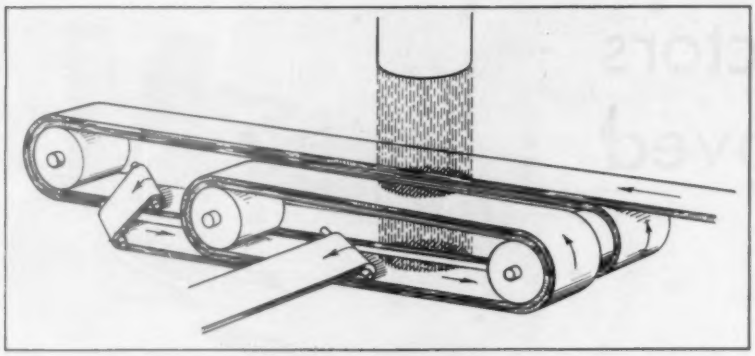

FIG. 7. FILM IRRADIATION SCHEME assures uniform dose. Each set of rollers carries film through electron beam a number of times; film side is reversed on second set of rollers

must be calculated for each specific operation because the dose level and utilization of the available energy are usually the overriding parameters. Electron-beam generators can cost in the range of $50,000–$300,000, depending on the power output and type of equipment. In terms of cost per unit of energy, resonant-transformer types, for example, range between $10,000 and $15,000/kw output and electrostatic generators range up to $35,000/kw. Accelerators in the $5,000 to $15,000/kw range have been reported (NU, August '60, p. 52). Actual operating costs, including maintenance and power but not amortization of initial investment, presently run 35–50¢/kwh for resonant transformers and $1.00/kwh for electrostatic machines. Beam-generator manufacturers look toward future costs of 10–20¢/kwh.

Beam utilization. Because electrons cost money, complete utilization of the electron beam is important. Electrons are usually lost in two ways—they scatter beyond the width of the material being irradiated and they pass through the material without being absorbed. Figure 7 shows an irradiation arrangement used by GE for film or flat-sheet polyethylene designed to minimize the losses. A web is built up of a number of layers to provide the cumulative thickness sufficient to absorb all electrons. In the continuous irradiation process of Fig. 7, film passes through the beam area many times on either of the two sets of rollers absorbing an incremental dose each time. This results in uniform irradiation along the film length.

The distribution of dose in the lateral direction depends on intensity and the lateral distribution of radiation and the width of the film and its distance from the exit window of the generator. In Fig. 7 the inner edges of the two parallel webs of film receive the most intense radiation. The inner edge of the web on the first set of rollers is transposed so that it becomes the outer edge of the web on the parallel set; and hence, receives a lower level of radiation as it passes through the electron beam a second time. Radiation-dose gradients of less than 10% can be obtained with this arrangement even when the energy is from a point source and has a conical distribution of intensity.

Polyethylene-insulated wires must be handled somewhat differently from film. Sequoia has reported in full detail on a commercial process (*15*). Briefly, festoons of wires are arranged so that a single wire moves laterally across the width of the electron beam during multiple passes to accumulate a uniform integrated dose. Proper roller or spindle design twists the wire on its own axis to counteract the shielding effect of the copper wire. Large-diameter thick-walled cable can be irradiated in much the same way, but should be rotated directly in the electron beam so that the heavy tangential thickness gets a uniform dose.

Molded parts present more of a problem. Multiple passes under the beam in different positions, tumbling or reflection of the beam to restricted portions of the article being irradiated have been used to achieve uniform irradiation. Usually the efficiency of beam utilization in this type of operation is considerably less than that obtained with continuous materials like wire, sheet or film.

The dose given the material is easily controlled by governing the voltage and current of the generator, position of the article in reference to the source window and the duration of time in the radiation field. The currents to the scan coil and the tube-envelope temperature are useful in checking that the scan-circuit is operating correctly and assuring that none of the electrons are being dissipated within the equipment. Many monitoring systems are available that have proven useful for measuring the actual incident or absorbed radiation (NU, Oct. '59, p. 57). Most involve bleaching of dyes (*11, 12*), easily measured physical-chemical changes (*13, 14*) or direct measurements of the radiation field itself, such as ionization chambers or the heat built up in thermocouples. The latter two are best suited for continuous monitoring.

One usually supplements the control measurements with a direct measure of the effects of irradiation on the product through a measurement of some critical property. Stress relaxation of film, deformation of wire coatings or heat distortion of molded articles are common. These give positive proof that the material is correctly irradiated and yield the dose level from calibration curves.

TABLE 3—Shrinkage versus Orientation*

Prestretch (uniaxial)	*Shrinkage 150°C*
10%	5%
80–100%	45%
275–300%	75%

* Irradiated low-density polyethylene.

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Semiconductors Yield Improved Electron Multiplier

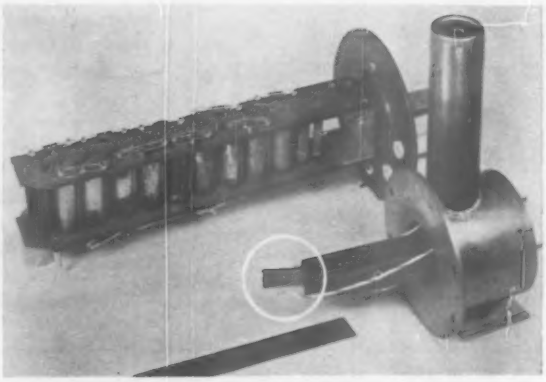

FIG. 1. NEW MAGNETIC ELECTRON MULTIPLIER (within white circle) is dwarfed by 19-stage electrostatic multiplier it replaces

Marriage of the semiconductor and the magnetic electron multiplier has produced a detector that is extremely sensitive and fast and yet is very small in physical size and practically noise free

by FREDERICK A. WHITE, JAMES C. SHEFFIELD and WILLIAM D. DAVIS*
Knolls Atomic Power Laboratory, General Electric Company, Schenectady, New York

THERE is an increasing demand in fields such as mass spectrometry for a positive ion detector that can measure ion currents as low as 10^{-14}–10^{-19} amp —that is, count single positive ions. Moreover to carry out the sophisticated mass-spectrometer measurements that are becoming so important to nuclear technology (see box), the physical size of the detector must be small. For example, one would like to set two detectors side by side to count simultaneously the ions from two isotopes differing by only a single mass unit. But in a conventional mass spectrometer the dispersion (or physical separation) of the two beams at the point of detection is of the order of $\frac{1}{10}$ in.

We have been able to achieve both of these goals—extreme sensitivity and small size—in the form of a magnetic electron multiplier with semi-conductor dynodes (Figs. 1 and 2). [In a magnetic electron multiplier (Fig. 3) perpendicular electric and magnetic fields cause the secondary electrons to move in cycloidal trajectories in the space between the two parallel plate dynodes; each cycloidal loop corresponds to a multiplication stage in a conventional electrostatic multiplier.]

In addition to size and sensitivity, the new detector operates with virtually no noise, can be used as a windowless counter in vacuum systems, and does away with the "resistor string" usually needed to supply dynode voltages.

The detector has proved to have many advantages over the 19-stage electrostatic multipliers (*1*) we had been fabricating for use with mass spectrometers. The latter detectors [of the Allen type (*2*)] could, with suitable pulse selectors and scaling circuits, be pushed almost to the desired limits of sensitivity; their large physical size, however, all but precluded arrangements such as the dual detector system mentioned above. [Two 19-stage multipliers have been used on a multistage spectrometer (*3*), but only under rather special conditions.]

Multiplier Description

The new magnetic electron multiplier differs from previous models (*5*, *6*) in that its dynodes are made of a bulk semiconducting material (silicon)* (see Fig. 2) rather than metallic oxide. Besides serving as the mechanical dynode structure the silicon also provides the high electrical gradient needed to accelerate the secondary electrons. Dynodes formed of solid semiconducting material rather than films of metallic oxides on an insulating base offer several advantages. High uniform potential gradients can be applied to the dynodes without "burnout"; this allows a device with high gain per unit length. The semiconducting surfaces need no treatment or special "activation" and the device can be exposed to the atmosphere indefinitely.

A disadvantage is that, at present, the dynodes must be cooled to make their resistivity suitably high. (Other semiconducting materials, however, may soon be available which will oper-

* PRESENT ADDRESS: General Electric Research Lab., Schenectady, N. Y.

* Interest in semiconductors originally stemmed from related work by one of the authors that demonstrated the ability of very small semiconducting crystals to detect positive ions and alpha particles (*4*); at present the crystals appear limited to ions of high energy and low mass (50-kv He ions).

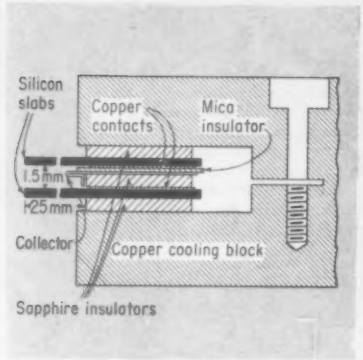

FIG. 2. PHYSICAL ARRANGEMENT of semiconductor dynode slabs in multiplier

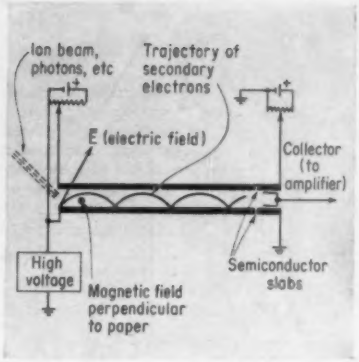

FIG. 3. ELECTRON TRAJECTORY in E and M fields between parallel-plate dynodes

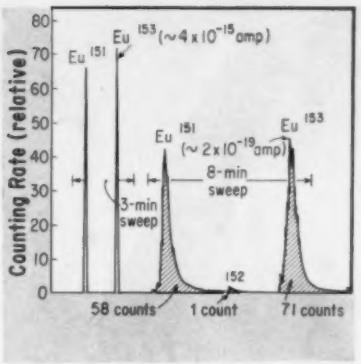

FIG. 4. MULTIPLIER COUNTING RATE as field changes in mass spectrometer

ate at room temperature). This inconvenience of cooling is compensated by the distinct advantage that the device has a thermionic emission or "dark current" of virtually zero. This feature makes the device a candidate for applications that involve exceedingly low counting rates.

The two slabs shown in Fig. 2 that form the parallel plate dynodes are of n-type gold-doped silicon. The resistivity of this material is of the order of 10^5 ohm-cm at room temperature. At an operating temperature of $-50°C$, however, the resistivity increases to approximately 10^7 ohm-cm—large enough to maintain high voltage gradients with only microampere currents. The dimensions of the pieces sawed from the ingot were 2 cm × 5 cm and 0.5 mm thick. In practice only 2-cm lengths are needed to obtain a gain of 10^6. The additional length merely serves as a mechanical support that connects to a copper cooling block attached to the Dewar cooling reservoir. Thin sapphire wafers between the silicon slabs and the copper block provide electrical insulation and at the same time the thermal conductivity needed for cooling. A 1-mm-thick sapphire piece functions as a spacer and insulator between the two parallel silicon slabs. The high-voltage wires, after receiving an ultrasonic "tinning," are soldered across the leading edges of the multiplier. The low voltage end of the semiconducting slabs are painted with bright gold. Thin copper foil forms the low bias voltage and ground connections (the latter is sometimes also connected to a small bias potential). The collector (shown schematically in Fig. 3) is a folded metallic ribbon insulated from the slabs by a mica sheet.

The gain or amplification of the semiconductor multiplier can be varied over a wide range. The total current gain is $K\gamma^n$, where K is the average number of conversion electrons generated from the primary particle or photon, γ is the average secondary electron yield per "stage" or cycloidal "loop," and n is the effective number of "stages." In the present device a 10-kev positive ion yields 2.5 secondary electrons.

Both gain per stage and total number of stages depend on the voltage gradient and the externally applied magnetic field. For a fixed voltage gradient, an increase in the magnetic field increases the number of stages per unit length but decreases secondary-electron yield per stage. Thus the device exhibits a broad maximum with respect to variations in magnetic field. The radius of the cycloidal generating circle is equal to mE/eH^2. Figure 3 also indicates that the intercept of the cycloid on the lower dynode (and hence the interstage distance) can be varied by the bias voltage. For a voltage gradient of 1,500 volts/cm, a bias voltage of 500 volts, and a magnetic field of 1,000 gauss, the radius of the generating circle is approximately 0.3 mm. This corresponds roughly to an interstage distance of 1 mm.

Mass Spectrometer

As an example of the multiplier's performance Fig. 4 shows its response as an ion detector for a mass spectrometric analysis of europium. The detector was placed in the fringing field of the magnet of an 180-deg mass spectrometer at a point where the field strength was approximately 1,000 gauss. We recorded counts as we increased the field at a uniform rate past the two magnetic-field values at which Eu^{151} and Eu^{153} ions enter the multiplier. The counts for the two isotopes of europium are displayed at two different magnetic "sweep" or scan speeds and at two different positive ion currents. The 3-min sweep is a recorder readout of the pulses from the multiplier, after they have gone through an amplifier, pulse-selector, a scaling cir-

Mass Spectrometry in Nuclear Technology

The art of mass spectrometry holds the key to many sophisticated measurements in the nuclear field. Measurements of atomic burnup, neutron-capture cross sections and power distribution studies in reactor cores depend on the ability to determine precise ratios of isotope abundance, often from micromicrogram quantities of material. For instance, studies that involve isotopes formed by neutron capture pose the problem of measuring the small fraction of atoms converted from mass m to mass $m + 1$.

In the field of radioactive tracers, the number of radioactive isotopes available is limited. In many instances stable or long-lived isotopes whose mass ratios can be accurately determined in a mass spectrometer offer significant advantages—both in sensitivity and precision—in competition with radionuclides.

FIG. 5. MULTIPLIER PAIR performs simultaneous count on ion beams one mass unit apart in 180-deg mass spectrometer

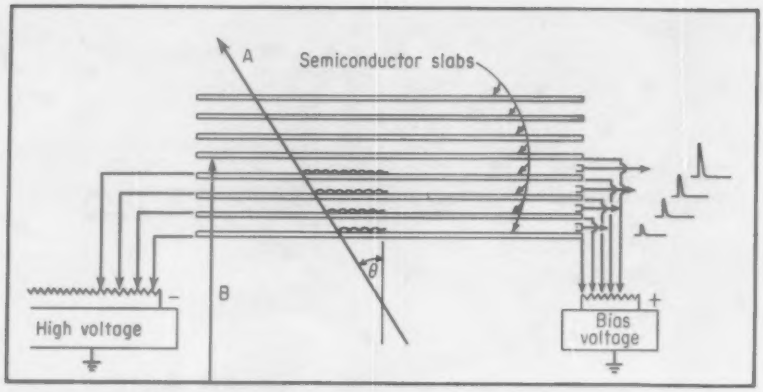

FIG. 6. SEMICONDUCTOR-DYNODE STACK would indicate direction of ionizing particle. Incident angle θ is related to ratio of pulse heights from successive dynode pairs. Stack would be similar in function to emulsion stack now used

cuit and a counting-rate meter.

To demonstrate the zero "dark-current" advantages of the device, the positive ion beam current was reduced so that only about 1 ion/sec was incident on the multiplier (comparable to background currents of many conventional devices). The magnetic sweep was adjusted so that an 8-min interval was required to "scan" three mass numbers. The total of 129 positive-ion counts detected by the magnetic multiplier determine a value for the isotopic ratio that agrees with the accepted one within the statistical error. Thus the magnetic multiplier arrived at an approximate isotopic abundance ratio through analyses of only $\sim 3 \times 10^{-20}$ grams of the two isotopes.

Of even greater interest is the single count observed at the 152 mass position, the only pulse recorded in the four-minute magnetic sweep between the 151 and 153 positions. This single count is *not* a background count, but an actual "impurity" peak (probably Sm^{152}), which was observed in the spectrum at higher ion-beam intensities.

An appreciable gain in ion collection efficiency can be achieved by the simultaneous detection of two or more isotopes with a system like the double magnetic multiplier assembly shown in Fig. 5. This device has a fixed "dispersion" (distance between the two dynode pairs) corresponding to the mass separation of adjacent barium isotopes in a 180-deg, 30-in.-radius mass spectrometer. We are now constructing a double multiplier with a variable interelectrode spacing that will separate any two adjacent mass numbers.

In practice the maximum counting rate is a function of the steady-state current flowing through the semiconductor slabs. At dry ice temperatures, the gold-doped silicon slabs pass a current of 1 μa at 2,500 volts. For fast counting (e.g., 10^5 counts/sec or 10^{-14} amp), a gain of 10^6 would make the output current equal to 1% of the "bleeder" current. At counting rates of 10^6 per second and greater, a variation of bleeder current was, in fact, observed. In principal, however, there are few limitations to either high-or low-counting-rate applications of the device. The exceedingly short total trajectory of the electrons (10^{-9} sec) gives a rise time considerably less than that of most electronic circuitry.

Other Applications

A number of other potential applications of the semiconductor magnetic multiplier appear intriguing, although only a few tests have been made to date. As a particle detector the multiplier performs as expected with alpha particles and presumably will detect any particle that can be detected by a conventional multiplier. A B^{10} coating along the leading edge of the device would convert it to a neutron detector —the alpha particles from the (n,α) reaction would generate secondary electrons.

Figure 6 demonstrates another possible application. Consider a high-energy particle B incident on an assembly or matrix of semiconducting slabs. The range of the particle could be given by the number of multipliers or channels triggered. Directional paths could be estimated by analyzing the pulse-height distribution from the slab array in suitable output circuits. Silicon absorbs radiation approximately as aluminum does; hence a matrix of eight thin slabs ($\sim$0.005 in. thick) could probably be constructed for high energy protons, deuterons or other particles from accelerators.

Because of the negative temperature coefficient of resistance of gold-doped silicon the multiplier could measure the environmental temperature at the same time it is counting particles. With a high-impedance voltage source, the gradient along the slabs and hence the pulse heights will decrease with increasing temperature. This dual function might be useful for space missions.

The multiplier also might function as an image intensifier. Although no tests have been made, it is conceivable that any initial geometrical distribution of secondary electrons produced at the input would be preserved during the multiplication process and give a duplicate image at the output on a fluorescent screen or other readout device. Thus the device would amplify either light or electron images.

* * *

It is a pleasure to acknowledge the collaboration of Robert Thomas and David Hartman of the General Electric Semiconductor Products Division. Without their assistance in supplying material, this work would not have been possible.

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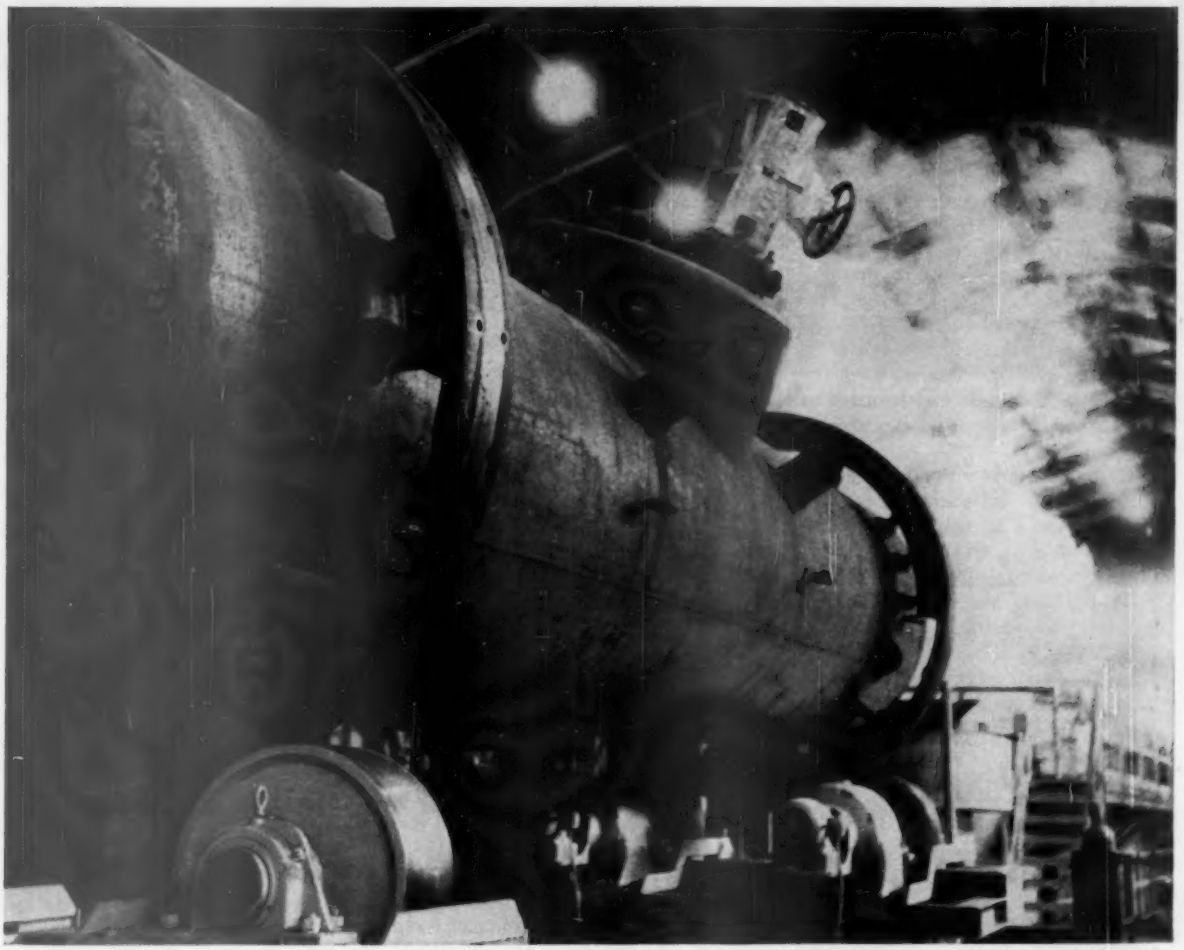

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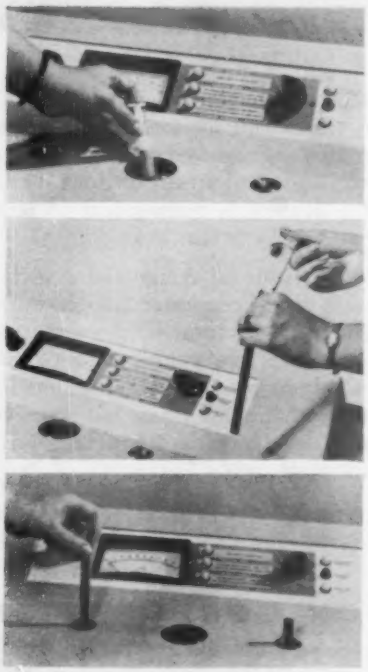
Punched Tallies Keep Exposure Records

Keeping health-physics records can be as difficult as getting them, especially if you have several thousand workers building nuclear submarines. So Electric Boat has devised a punched-tally system to tell quickly which men are qualified to work in radiation areas and which are not. It saves the many man-hours that used to be wasted as men stood in line to have records checked.

Each man starts with a blood count, which, when satisfactory, qualifies him to receive 16 weekly tally cards printed on a Dennison Dial-Set machine. As he goes to work, he picks up a dosimeter and this week's card, which is his admittance to a radiation area. As he leaves he surrenders card and dosimeter to an inspector who adds the dosimeter reading to the total on the card and returns the card to the man's folder. When anything is wrong (large accumulated exposure, blood count due) a colored flag from another pocket in the folder goes in front of the dose-record card to tell the inspector that special action is required when the man appears for work tomorrow. After 16 weeks the cards are gone; a new blood-test is required, and the cycle starts over again with a new set of cards that is good for the next period.

DIAL-SET PRINTER prepares cards on which Electric Boat records radiation exposures

Tracers and Automation Determine Blood Volume



BLOOD-VOLUME MEASUREMENT requires counts of tracer (top), preinjection blood (center), postmixing blood (bottom). Computations are automatic

In less than 15 min a surgeon can have a blood-volume determination accurate to ~2%. A small cart that he can roll up to the patient's bed or operating table contains not only all the counting equipment for an isotope-dilution determination but also the logic elements to compute his answer. The system, which is manufactured by Atomium Corp, an affiliate of Perkin-Elmer, has been developed by John A. Williams and Jacob Fine of Beth Israel Hospital, Boston, and Harvard Medical School.

Measurement of the two to six quarts of blood in a human system has always been difficult, but very significant. Chronically ill persons may have 40% more or less blood than their normal volume, but the central nervous system squeezes the blood vessels or allows them to expand so that you might never know. If you underestimate, your patient may die of shock on the operating table; if you overestimate, too rapid transfusion may fatally overload the cardiovascular system.

Yet until radionuclide determinations came along, most determinations were wildly inaccurate. Three physicians who tried to estimate blood volumes from usual clinical observations found that they were right in only four out of 32 tries. Various dye and dilution methods (with distilled water, carbon monoxide, red dye and Evans blue) are better—but not good enough.

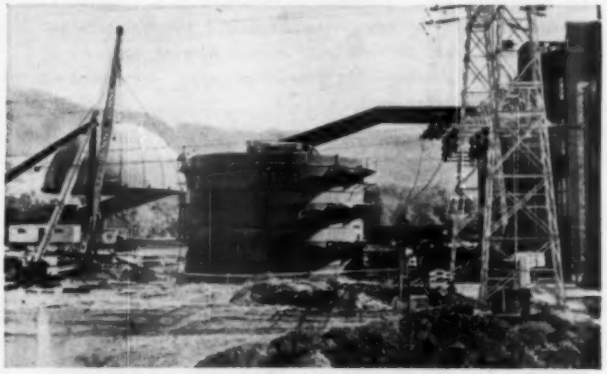
Radionuclides do a better job, and the new method speeds and simplifies the measurement. With the Atomium device ("Volemetron") the doctor uses a set of push buttons to make the necessary counts (patient's blood before injection, syringe with tracer, syringe after injection to account for tracer left in syringe, patient's blood after 10–12 min of mixing). The answer appears on a meter calibrated in liters. Iodine-labeled protein measures total volume; chromium-labeled red cells measure red-cell volume. You can make as many as five determinations in a row with permissible amounts of tracer and still get results accurate within 5%.

A valuable characteristic is simplicity: no special glassware, volumetric pipettings, aliquot dilutions nor specially trained personnel are required for operation of the system.

FOR YOU TO ADVANCE THE STATE OF THE ART

The Westinghouse Testing Reactor facility in Waltz Mill, Penna. provides the reactor designer with a completely instrumented facility from which he can derive empirical data to correlate with his design equations. This kind of "in-field" approach enables Westinghouse to stay in the forefront of reactor technology.

FOR A LARGE SCALE EXPERIMENTAL REACTOR



Westinghouse scientists and engineers will soon enjoy the unique technical experience of being able to work directly with a 5 electrical megawatt closed cycle water reactor at Saxton, Pennsylvania that will supply electricity for a portion of the GPU System. The entire experimental program for this installation will be centered around concepts aimed at significantly reducing the cost of producing nuclear power. These experiments will entail work in almost every phase of reactor development.

Career openings for qualified scientists exist in many areas. Some of these areas are listed below.

PHYSICIST: Capable of independent work in reactor physics, to direct research and development on advanced reactor concepts, or to perform and direct reactor physics and nuclear design work on cores nearer completion.

SENIOR STRESS ANALYST: To conduct test programs for the analysis of stresses in reactor components with emphasis on thermal stresses due to internal heat generation. Requires an M.S. or Ph.D. degree in Applied Mechanics or a closely related field with 3 or more years experience in stress and vibration analysis. Should have experience in plasticity and fatigue analysis and a familiarity with reactor materials and their behavior.

SENIOR ENGINEER: Alloy development on reactor materials and fuels with particular emphasis on control rod and cladding materials. M.S. degree in metallurgy with three years experience in reactor materials.

ENGINEER: To perform analyses and detail specifications of fuel cycle requirements for WTR; to perform analyses of experiments to be inserted in the reactor. Must be able to determine reactivity losses associated with fuel depletion and experiments inserted or removed from the reactor. These analyses will include neutron flux perturbation, power production and safety analysis of experiments and their effect on the reactor. Must possess a B.S. in reactor engineering or an M.S. in physics with two years experience in nuclear design of reactors.

ENGINEER OR SCIENTIST: To perform reactor physics calculations on reactor cores which involve problems of the development and application of theoretical methods, founded on basic theory, to technical programs concerned with the design and construction of large power reactors. M.S. degree in physics or nuclear engineering.

SCIENTIST: Involves the mathematical analysis of problems in reactor physics and engineering with emphasis on the development of digital computer programs or adaptation of existing programs to meet special requirements. B.S. degree in mathematics, physics or engineering with emphasis on applied mathematics and experience in digital computer applications.

MGR. PHYSICAL METALLURGY SECTION: The position requires a man well rounded in the fundamentals of physical metallurgy and with 5 to 10 years experience. Must be experienced with the effects of radiation on metals both fuel bearing and non-fuel bearing. The position will also involve stainless steel and carbon steel alloy development and development in the field of other high temperature metals and ceramics such as graphite, beryllia or other ceramics used in the nuclear industries. A strong foundation of physical chemistry is desirable since there will be problems concerning corrosion. Must be able to assist project design engineers in problems regarding the fatigue, creep and brittle fracture of metals and alloys.

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

If you qualify for any one of the above positions, write immediately to: Mr. C. S. Southard, Westinghouse Atomic Power Division, P. O. Box 355, Dept. Y-13, Pittsburgh 30, Pa.

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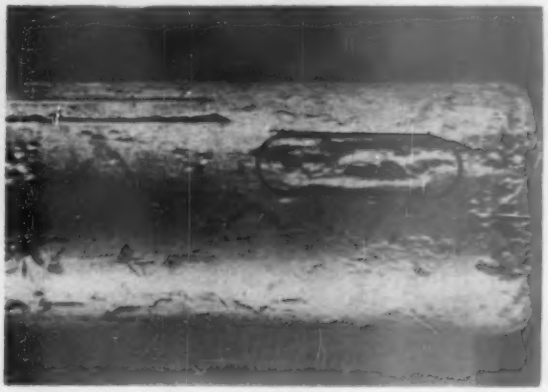
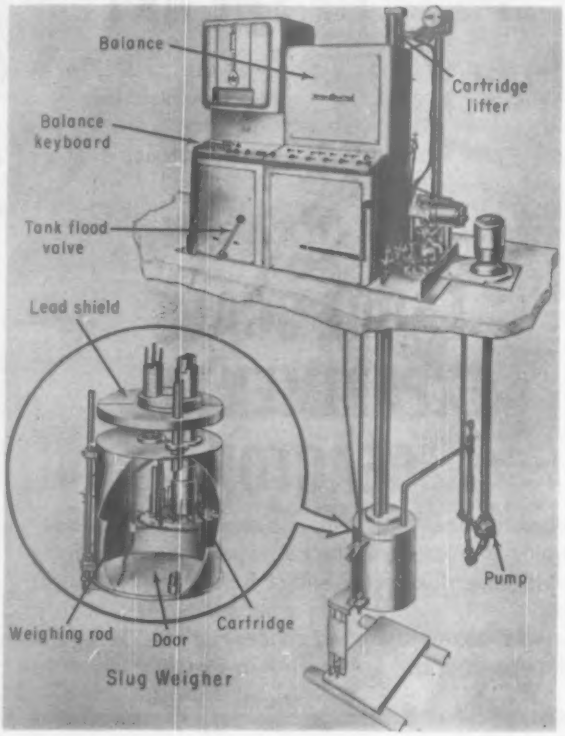
Testing Irradiated Fuel at Hanford

by JOHN M. FOUTS, *Hanford Atomic Products Operation, General Electric Co., Richland, Washington*

Improving the radiation lifetime of the natural-uranium, aluminum-clad production fuel is a major activity at Hanford. Laboratory researchers are seeking out the combination of water quality and aluminum alloy that gives the optimum corrosion resistance under irradiation; they are trying new uranium-fabrication techniques to achieve fuel elements with greater dimensional stability; and they are studying ways to improve the metallurgical bond between the uranium core and the aluminum can. Essential to these efforts is Hanford's on-site facilities for examining irradiated test elements as they emerge from the reactor. Shown here is equipment Hanford has developed to check corrosion, dimensional stability and bond integrity.



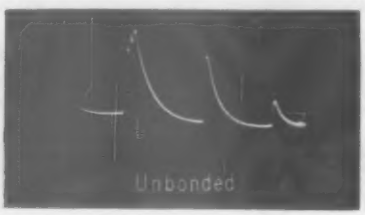


CORROSION ANALYSIS of irradiated fuel consists of a comprehensive visual examination combined with accurate weight determination by remote weighing equipment pictured above, right.

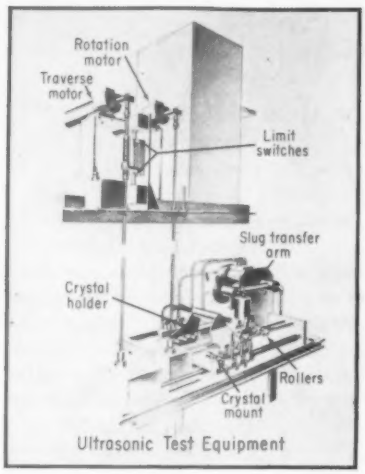
A discharged slug is first examined for signs of localized corrosion attack through a binocular periscope (not shown) while it is held and rotated under 17 ft of water by a remote manipulator. The slug is next dipped in chromic-phosphoric acid—a mixture that dissolves the corrosion film without attacking the aluminum can wall (NU, Jan. '56, p. 30). The slug is then weighed in the underwater weighing equipment to an accuracy of 1 part in 100,000, and the weight loss due to corrosion determined by comparison with the preirradiation weight.

The weigher accommodates 16 fuel elements in the underwater tank at a time. Prior to weighing, the water is pumped out of the tank, and the cartridge, slugs and weigh rod are dried in warm air. Each slug is remotely placed on the weigh rod and weighed with a key-board-operated analytical balance at a console directly above.

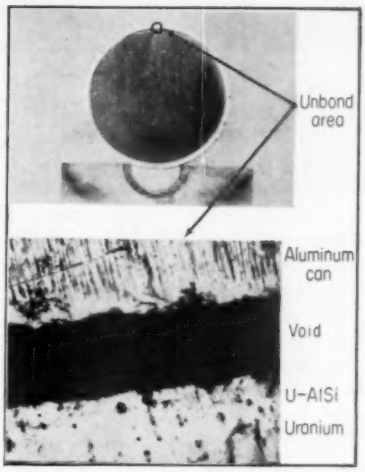
The weight loss, correlated with the visual examination, gives a complete picture of the corrosion. A weight loss of 10–15 gm, uniformly distributed over the entire surface, would not be serious; however, if visual examination indicates a localized attack, this same weight loss would be a serious problem. The figure above, left shows a fuel element with a weight loss of only 5.3 gm but in which localized cavitational erosion attack has exposed bare uranium to the cooling water.



BOND TEST employs underwater ultrasonic tester (at top, opposite page) to check on the metallurgical bond between the uranium core and the aluminum cladding after irradiation. Tester works on the pulse-echo principle and is similar to the equipment that bond tests all production fuel prior to irradi-



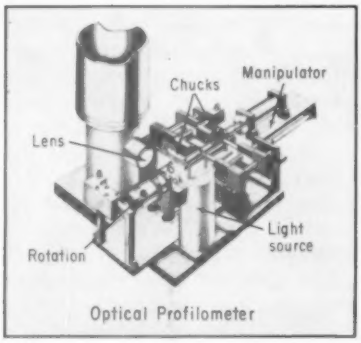
Ultrasonic Test Equipment



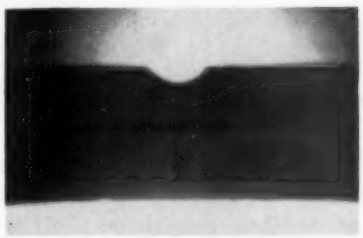
ation (NU, July '61, p. 92). The cylindrical slug, rotating at 180 rpm and advancing axially $\frac{1}{16}$ in. per revolution, spirals past a quartz crystal that interrogates the slug surface with 20-megacycle pulses at a repetition rate of 3,000 pps. When a pulse hits an unbond area, vibrations set up in the unbonded can wall alter the shape of the echo pulse. As the figure at the bottom of the opposite page shows, the echo decays at a lower rate and exhibits wiggles in the pulse trace.

The numbers quoted above correspond to 18 interrogations/cm along the spiral path traced on the fuel surface or 0.02 in. between interrogations. The tester will measure either the total unbonded area of a fuel element or sizes of individual unbonded regions. Each 8.9-in. slug requires 40 sec to test. A calibration is run twice daily with a standard slug containing two unbonded areas, each 3.8 cm in length, one 0.60–0.65 cm in width and the second 0.75 cm in width. The equipment is expected to discriminate between the two areas.

One of the first irradiated fuel elements tested was found to contain an unbond area extending 3.5 in. along the slug length and 1.5 in. circumferentially. When the slug was sectioned at the center of the area in question, an unbonded region was revealed (above, right) ~9 mils wide radially and of the dimensions predicted by the tester.



Optical Profilometer



DIMENSIONAL STABILITY of irradiated fuel is checked by optical profilometer (above, left). The fuel element held between the two chucks of an underwater manipulator is moved through a beam of light. An optical system projects the top and bottom shadow of the fuel element magnified 25 times onto a translucent screen. (Figure at right above is the shadow of an element with an area of localized corrosion 17 mils deep at the top center of the shadow.) By rotating the element as it travels through the light beam, one can plot a profile of the entire element. This information yields the diameter of the element, the ellipticity (two diameter measurements taken 90° from each other) and the single-throw warp. Comparison with preirradiation data, and with similar data from normal production fuel elements, determines the dimensional stability of the irradiated element.

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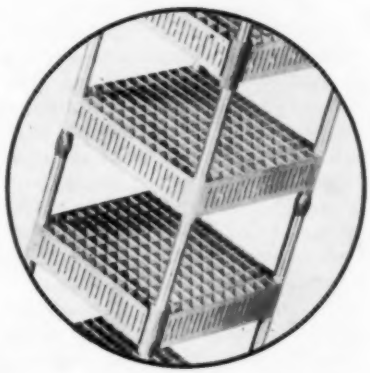

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Fermi Passes Nonnuclear Tests

While the courts were deliberating the legality of the Enrico Fermi Reactor's permit for construction (NU, July, '61, p. 21), the reactor plant itself has been making encouraging progress in working its way through a scheduled series of nonnuclear checkouts. The aim of the series was to find out whether the assembled components of the primary system—the world's largest sodium system—would function as planned hydraulically and mechanically. Would the pressure-vessel closure, piping and pump connections and other miscellaneous seals prove to be leak tight to the high-temperature pressurized sodium coolant? Would complicated mechanisms such as the rotating shield plug, fuel-handling mechanism, control-rod drives and sodium pumps, which operate with clock-like precision as individual components at room temperature, work just as well as part of a whole system at the elevated temperatures of liquid sodium? With nonnuclear tests of the primary system essentially complete, Atomic Power Development Associates can report that, except for a temporary problem with crudding, everything functioned exactly as planned.

The tests were conducted on the actual reactor system plus one of the three coolant loops. The reactor was complete except for the presence of fissionable material in the dummy fuel elements. After a checkout with 500°F air, the system was charged with liquid sodium and held at 500°F for over 4 months; it was then raised to 1,000°F for a week (core-outlet design temperature is 800°F) and subsequently returned to 500°F where it has remained ever since. Operating experience with sodium has been especially encouraging —there was no evidence of corrosion, leaks or deterioration. After its transfer to the primary system, the 345,000-lb charge of sodium was purified by circulating overflow to the reactor cold trap until the oxide content was less than 10 ppm. Purity checks during this and subsequent operations showed very little pickup of impurities from the system or from leaks, attesting to initial system cleanliness and leaktightness. Through a quartz window the sodium surface looked silvery bright, more like a large pool of mercury than a material that oxidizes readily.

The operation of the sodium system has proved that with proper precautions clean oxygen-free sodium systems can be built and maintained free of corrosion and mass-transport problems.

The unexpected problem with crud during the 1,000°F operating period when about 1,000 ft^3 of carbon dioxide baked out of the canned graphite in the rotating plug and escaped through vents into the argon cover gas. The carbon reacted with the sodium surface to form a sodium-carbonate crud that gummed up mechanical devices, interfering with their operation. However, the carbonate, like sodium oxide, is slightly soluble in hot sodium, so that APDA was able to dissolve it off from all the mechanisms but the rotating plug by lowering them down into the sodium pool. Although the carbonate dissolves very slowly (the solubility is only 100 ppm in 500°F sodium), this method proved an effective way to remove crud. Recently the sodium level was raised to contact the rotating plug and the latter is now soaking free of the carbonate. [The Fermi crud is similar in chemical composition to the material that plugged coolant channels in SRE (see NU, Jan. '60, p. 107) but was present in much smaller amounts.]

Designers expected the graphite to release carbon dioxide but not so large a quantity and so suddenly (within a 24-hour period). The problem, APDA feels, could have been avoided by investing in a higher quality graphite. Because the system has outgassed at 1,000°F no more release of carbon dioxide is anticipated at the normal operating temperature of 800°F, except, possibly, for small quantities produced through the action of radiation on the graphite, which could be absorbed in the sodium with no difficulty.

In summary APDA is satisfied that the nonnuclear tests of the primary system have accomplished their goal. They have demonstrated that the integrated system can function at design temperatures with good dimensional stability. During this time temperature, pressure, flow and sodium-level measuring devices, and the auxiliary pumps all operated satisfactorily. Prototype control-rod operation, activation of the fuel hold-down mechanism, and rotation of the reactor-vessel plug were successfully demonstrated. All three main sodium pumps (the world's largest pumps for sodium service) have operated for several hundred hours and one of the pumps has operated smoothly and quietly for over 2,000 hr at various loadings up to a maximum of 13,100 gpm. One of the important accomplishments during June was the successful operation of the three main pumps in parallel.

Afterheat May Help to Recover Rocket Booster

The afterheat from a nuclear booster —usually considered an unavoidable headache by propulsion-reactor designers—may be put to good use in recovering the booster to avoid wasting its U^{235} core (worth ~$300,000 for a 10^6-lb-thrust booster). J. W. Eerkens (Aerospace Corp.) calculates that the thrust provided by gaseous propellant heated by the afterheat is enough to "de-orbit" the booster and place it in a once-around-the-earth trajectory that brings it back to its launching site. The operation must be carried out immediately after payload separation because the afterheat decays quickly; most of the afterheat thrust is expended within 10 min after reactor shutdown. Accordingly Eerken's calculations show that the afterheat thrust available at the end of a 90-min de-orbiting trip around the earth would be too small to supply the braking needed by the booster as it re-enters the atmosphere at this point.

The afterheat coolant-propellant would feed from a separate pressurized storage tank, through the reactor core, and out the main nozzle. Hydrogen, ammonia and propane are possible candidates for this task, with hydrogen giving the greatest thrust per unit of tankage weight. Thrust verniers would turn the booster around so that the nozzle is in the correct retrothrust direction before the afterheat thrust system is turned on.

(J. W. Eerkens, American Rocket Society Conference, Gatlinburg, Tenn. May 3–5, 1961)

Gaseous Suspensions—A New Reactor Coolant

by DONALD C. SCHLUDERBERG, ROBERT L. WHITELAW* and ROBERT W. CARLSON
The Babcock and Wilcox Co., Lynchburg, Virginia

A gaseous suspension of graphite—in which dispersions of micron-size particles are suspended in flowing gas—is a possible new coolant for power reactors (see Fig. 1). As a primary-loop heat-transfer fluid it promises significant advantages in performance over ordinary gas coolants. In recent work sponsored by the AEC and The Babcock and Wilcox Co. we have shown that gas suspensions (ranging in graphite density up to 10 lb/ft³) exhibit greatly improved heat transfer and heat transport compared with pure gases at the same pressure, temperature and velocity. This addition of solids to a flowing gas is an alternative to increased operating pressure as a means of bettering gas-coolant performance.

Analysis of test results from small heat-transfer loops point to significant reduction in size and cost of gas-cooled nuclear power systems because of the reduced pumping power, higher specific power, reduced coolant volume fraction, lower coolant pressure, smaller containment structure and lower fuel temperature possible with gas suspensions.

Because this is a completely new type of coolant, considerable research and development will be required to develop the technology to the point where reactor system components and special instrumentation can be satisfactorily designed and operated. No experience is available regarding behavior in large systems. The low theoretical pumping powers indicated for reactor coolant applications will be of practical value only if we can develop efficient centrifugal or axial-flow pumps. Positive displacement pumps tend to have higher efficiencies but their volumetric capacity is not sufficient for most primary coolant applications.

For reactor-coolant applications, it will be necessary to investigate material compatibilities, system chemistry and special problems such as the effect of pump failure upon heat-removal characteristics of the suspension. If the velocity drops to zero and the particles fall out of suspension, perhaps one will need to develop standby pumping equipment to quickly re-establish flow of at least the gas phase.

* PRESENT ADDRESS: Allison Div., General Motors Corp., Indianapolis, Indiana.

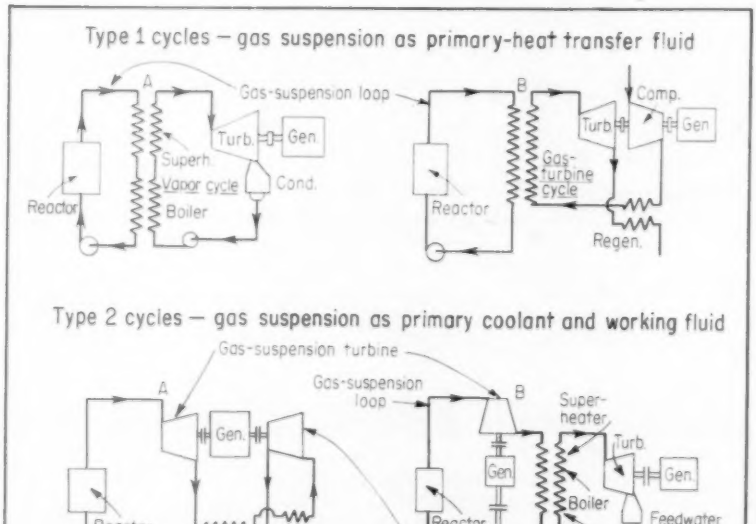

FIG. 1. GAS SUSPENSION CYCLES for nuclear power plants. Type 1 cycles look feasible now subject to successful development of primary-loop pump; type 2 cycles await development of gas-suspension turbines and compressors

Test Experience

To date the experience with small heat-transfer test loops has found gas-suspension systems remarkably free of erosion, plugging or adherence to system surfaces. A test loop with tube sizes ranging from 0.313-in. to 0.875-in. i.d. operated for more than a year without plugging except on two occasions when the graphite charged into the system had not been dried and outgassed (at 800°C). On these instances plugging occurred during cold startup immediately after the untreated graphite was added.

Visual inspection of loop components and chemical analyses of circulated graphite particles have showed no evidence of erosion. This can be attributed to the small particle size, the fact that graphite is more frangible than the metal walls of the system, and the wearing off of any sharp particle edges by continuous circulation in the loop.

This operating experience also has shown that gas suspensions will readily flow through needle, globe or ball valves. Properly arranged pressure-gage tubing will not plug unless there is a small leak in the tubing between gage and pressure tap.

We observed an unusual type of particle adherence on the heat-exchange surfaces of loop coolers at large heat fluxes with helium as the suspending gas. The particle coating completely fouled the heat-exchange surface but did not plug the tube. The formation of this coating may thus be associated with anisotropic Brownian particle motion along a temperature gradient in the gas-boundary layer. We believe this coating tendency can be suppressed by running at gas pressures above the 50–75-psig range at which it occurred. This difficulty was never noticed in heated sections of the loop or when heavier suspending gases (N_2, CO_2, CF_4) were used.

Preliminary tests show that gas suspensions are readily pumped by con-

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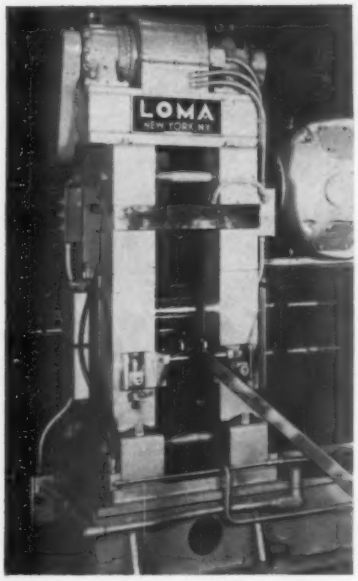
LOMA



A wide variety of metallurgical processing work can now be performed by a single mill facility due to the development of this compact and versatile LOMA 2-high/4-high Combination Rolling Mill. The equipment is suitable for both hot and cold work, and allows both shapes and flat stock to be rolled, with or without the application of tension.

The machine is equipped with extra large capacity mill housings, roll journals, universal spindles and drive transmission. This heavy-duty design allows the mill to take reductions of more than 50 per cent per pass while maintaining tolerances as close as 5 per cent of thickness.

Change-over from the 8½ in. x 10 in. 2-high to the 2½ in. & 8½ in. x 10 in. 4-high setup requires only 30 minutes. The 2-high arrangement is used for either hot or cold breakdown rolling of plate and sheet, and grooved rolls are also available to process rounds, squares and other shapes. In the 4-high setup strip is cold finish rolled to gauges as thin as 0.002 in.

The LOMA mill is furnished with high-strength steel housings, twin-handwheel or dual-motor wormdrive screwdowns, universal joint spindles, herringbone gearing, and an extra heavy-duty 25 h.p. variable-speed drive. The rolls are made of forged alloy steel and are hardened to 100 Shore Scleroscope. The roll necks are mounted in super-precision needle roller bearings having a total separating force capacity of 350,000 lbs. The bearings are continuously lubricated by a closed oil circulating system.

LOMA
MACHINE MFG. CO., INC.
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ventional blowers; however, these machines do not convert an appreciable portion of the kinetic energy imparted to the particles into gas pressure. Certain modifications to rotor and casing should correct this difficulty. Unless a fair amount of the particle energy can be recovered (say 50% or more), the potential advantage of lower pumping power will not be realized.

Heat transfer. We investigated the heat-transfer and pressure-drop characteristics of gas suspensions of 1–5-micron graphite (AGOT) particles suspended in N_2, He and CF_4 at densities up to 8 lb/ft³. The pressure varied from 30 to 130 psig, temperature from 90 to 1,100°F and velocity from 20 to over 200 ft/sec (*1, 2*). The heat-transfer data appear to be correlated by equations of the following form:

$$Nu = A(Pe_g)^a[(W_sC_s/W_gC_g) + 1]^b$$

where

Nu = Nusselt number, using gas thermal conductivity at average film temperature, tube i.d., or equivalent diameter of annulus based on heated surface

Pe_g = Gas Peclet number evaluated at average film temperature using tube i.d. or equivalent diameter based on wetted surface of annulus

W_s = Flow rate of solids

W_g = Flow rate of gas

C_s = Specific heat of solids

C_g = Specific heat of gas

A, a, and b are constants which depend on flow geometry. Values of the above constants for each of the correlations obtained are given in the table.

There is some doubt that the above correlations hold for values of $W_sW_g \leq 1.0$. The data of Farbar and Morley (*3*) in this range of solids loading indicate a different behavior. Representative points for values of $W_s/W_g > 1.0$ show fair agreement with gas-graphite suspension data.

Pressure drop. The data on pressure drop for circular channels without spiral ribbon turbulence promoters was found in good agreement (Fig. 2) with data for the flow of dense pulverized coal-air mixtures (*4*) for values $G_f \geq 275$ lb/ft²-sec. The pulverized coal-air mixtures exhibited a different characteristic below this flow rate. This may be due to the considerably larger pulverized coal particle size. Corresponding transition points, if any, for various graphite-gas suspensions were not observed.

The data for circular channels without a turbulence promoter show general agreement with the Moody-friction-factor curve for smooth tubes at lower Reynolds numbers but drops below this curve at higher Reynolds numbers. We believe these lower values arise from the suppression of flow turbulence by the suspended particles; the resulting flow characteristics are similar in some respects to those of a single-phase fluid in laminar flow. The friction factor was calcu-

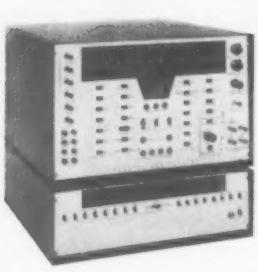
Heat Transfer Correlation Data for Gaseous Suspensions

Tube i.d. (in.)	*Spiral-ribbon turbulence promoter pitch/gap*	*Suspension gas-solid*	*Constants A/a/b*	*Pe_g range*
0.313 0.532 0.834 0.689	none	He-graphite N_2-graphite CF_4-graphite Air-pet. catalyst	0.020/0.80/0.45	2×10^3–4×10^5
0.313	2.36 in./0.051 in.	N_2-graphite He-graphite CF_4-graphite	0.036/0.77/0.58	3×10^3–3×10^5
0.532	4.0 in./0.081 in.	N_2-graphite He-graphite	0.017/0.86/0.58	3×10^3–1×10^5
0.834	6.5 in./0.074 in.	He-graphite N_2-graphite	0.0090/0.97/0.58	1×10^3–6×10^4
Annulus	0.992 in. od 0.750 in. id	He-graphite N_2-graphite	0.051/0.73/0.45	7×10^3–3×10^4

THERE MUST BE AN EASIER WAY!

THERE IS: *FAST* *

* In radiation analysis, accumulation of the energy distribution curve is usually followed by quantitative interpretation of the results. The most frequent first step in the interpretation is the determination of the intensity of individual lines by integration of the areas involved. With *FAST*, the operator selects a region of interest, depresses a switch, and the area of the selected region is quickly indicated in memory channel number one. The answer is then typed out by means of the IBM computer readout typewriter. Other regions of interest may be quickly integrated in the same manner. Answers are exact, and operation is simple and dependable. This is *FAST*. (Fast Area Sub-Totalling.)



MODEL ND-130A ANALYZER-COMPUTER

The Model ND-130A includes the analysis and summation circuitry (**FAST**) as well as spectrum stripping circuitry. It costs no more than the superb Model ND-130.

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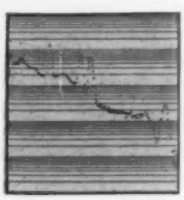
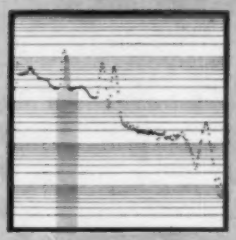
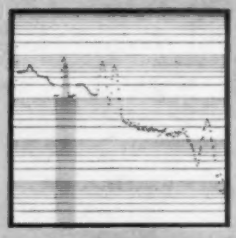


HERE'S HOW IT WORKS:

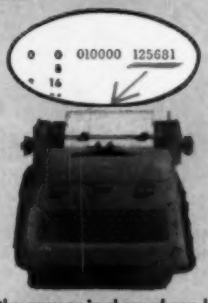


Step 1: Analyze the unknown radiation source. Correct for background counts, if desired, by utilizing the data reduction controls.



Step 2: Select any region of the spectrum by simple switch operations. The selected regions are displaced for instant visual examination. The channel numbers involved are indicated exactly by the switch settings.

Step 3: Depress the "Initiate computer cycle" button. The sum of all data points in the selected region, only, is accumulated in a second or two. The sum, divided by ten if desired in order to avoid count overflow, is recorded into analyzer channel number one.



Step 4: Read out the answer in channel one by means of the IBM computer readout typewriter. That's all. No more tedious adding machine operations. No more adding errors.

Precision of analysis and instrument dependability are nothing less than remarkable in the ND-130 series analyzers. For example, of sixty units delivered prior to July, all except one (probably damaged during installation) have operated without failure up to that date. No other analyzer model has ever approached this record. Almost flawless performance, combined with such features as punched tape read-in and read-out, internal data reduction, fast area sub-totalling, precision logarithmic curve display, and others, make this analyzer the best in the field.

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Gaseous Suspensions

This article starts on page 67

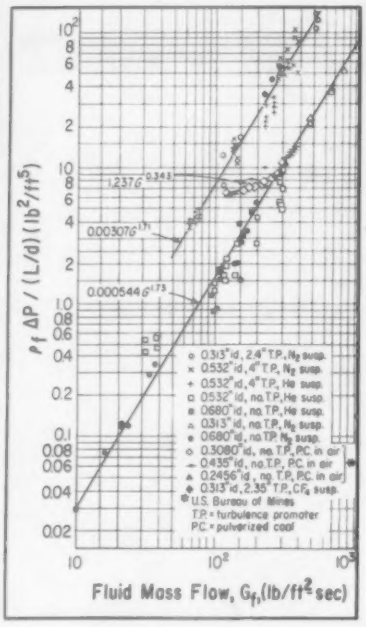
$\rho_f \Delta P / (L/d) (lb^2/ft^5)$
Fluid Mass Flow, G_f, (lb/ft^2 sec)
0.2376 $^{0.343}$
0.003076 $^{1.71}$
0.000544 $^{2.73}$
○ 0.313" id, 2.4" T.P., N_2 susp.
× 0.532" id, 4" T.P., N_2 susp.
+ 0.532" id, 4" T.P., He susp.
□ 0.532" id, no T.P., He susp.
■ 0.680" id, no T.P., He susp.
△ 0.313" id, no T.P., N_2 susp.
● 0.680" id, no T.P., N_2 susp.
◇ 0.3080" id, no T.P., P.C. in air
— 0.435" id, no T.P., P.C. in air
▲ 0.2456" id, no T.P., P.C. in air
◆ 0.313" id, 2.35" T.P., CF_4 susp.
* U.S. Bureau of Mines
T.P. = turbulence promoter
P.C. = pulverized coal

FIG. 2. PRESSURE DROP parameter vs gas-suspension flow for circular channels

lated by a compressible-flow equation derived by assuming a constant average fluid temperature.

Coolant Performance

The heat-transfer and pressure-drop data given above can be used to compare the coolant performance of gas suspensions with those of pure-gas systems. We can make comparisons based on each of the following criteria

- the pumping power required to maintain a given heat transfer coefficient on a square foot of heated surface as a function of solids loading.
- the heat removed per square foot of flow-channel cross section as a function of solids loading when the pumping power is a fixed percentage of the heat removed and coolant-temperature rise, maximum surface temperature, and film ΔT are constant.
- the effect on the inlet and outlet temperatures of a gas-cooled flow channel as a function of graphite loading assuming a limiting maximum surface temperature.

Pumping power. The results show that the addition of graphite to nitrogen or helium has an appreciable effect upon pumping power, especially when turbulence promoters are used. The following table lists values of pumping

M1238-1818 — *Range 18" x 18", working distance 9" to infinity. Reads to 0.001" up to 24" working distance. Protractor ocular reads to 3 minutes of arc. Image is erect.*

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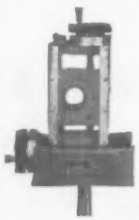

M1236-22— Range 2" x 2", reads to 0.0001". Working distance 5" to infinity. Shown with 19 mm mounting rod, and without telemicroscope. Instrument permits precise coordinate movement of other objects such as photo cells, probes, etc., in place of telemicroscope.

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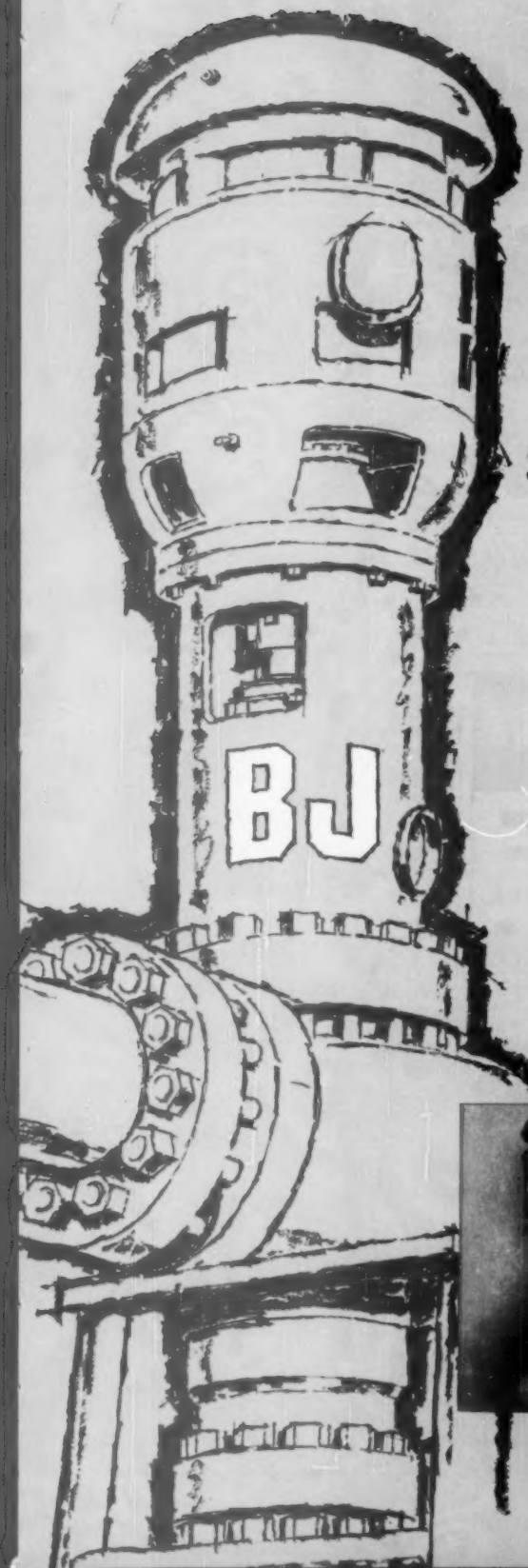

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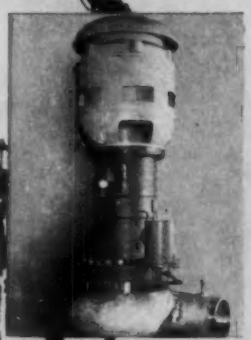

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power per square foot of heated surface to achieve a heat transfer coefficient of 500 Btu/hr-°F-ft² with the coolant at 300 psia and 800°F for pure He and N_2 gases; the suspensions had a fluid density of 8 lb/ft³. This density corresponds to solids loadings of 12 and 89 for the N_2- and He-graphite suspensions, respectively.

Pumping Power per Unit Area (HP/ft²)*

Coolant	*Turbulence promoter*	*No turbulence promoter*
He	1.50	1.50 (0.88)
N_2	3.80	6.30 (4.41)
He/Graphite	0.091	0.24
N_2/Graphite	0.140	0.52

* 0.532-in. i.d. tube 7.18 ft long.

The pure-gas values were obtained by extrapolating the gas-suspension relationships to zero-solids loading. Comparable values predicted from the Moody and Colburn relationships for the tube without a turbulence promoter are shown in parentheses. These figures show that gas suspensions offer a reactor-core and heat-exchanger performance vastly improved over that possible with gases, especially in combination with turbulence promoters.

Heat removed per unit flow area. Figure 3 shows the effect for a nitrogen/graphite suspension of solids loading upon $G_f C_f \Delta T$, the heat removal rate in Btu per hour per square foot with pumping power a constant percentage of total power. Coolant temperature rise, film ΔT, channel surface temperature and channel length are also held constant and channel diameter is a dependent variable. The helium curves are quite similar. (*Continued*)

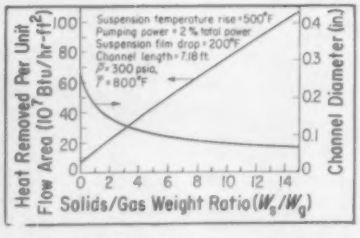

FIG. 3. HEAT REMOVED vs weight ratio for nitrogen/graphite suspension

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Gaseous Suspensions

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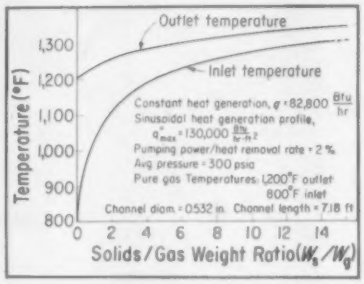


FIG. 4. TEMPERATURE of nitrogen/graphite suspension vs solids loading

Inlet and outlet temperatures. The coolant temperatures at the inlet and outlet of a gas-cooled heat source, such as a nuclear reactor, were determined as a function of graphite loading for a limiting coolant-channel surface temperature of 1,600°F and a channel power of 24 kw with a sine distribution. Figure 4 shows that the outlet temperature increased from 1,200°F to 1,350°F as the coolant density increased from that of pure nitrogen ($W_s/W_g = 0$) to 7.0 lb/ft³ ($W_s/W_g = 15$). The addition of graphite reduced the coolant temperature rise from 400°F to less than 50°F because of the increased coolant heat capacity.

Power-Plant Applications

The four cycle diagrams presented in Fig. 1 illustrate the range of applications of gas-suspension coolant to nuclear power.

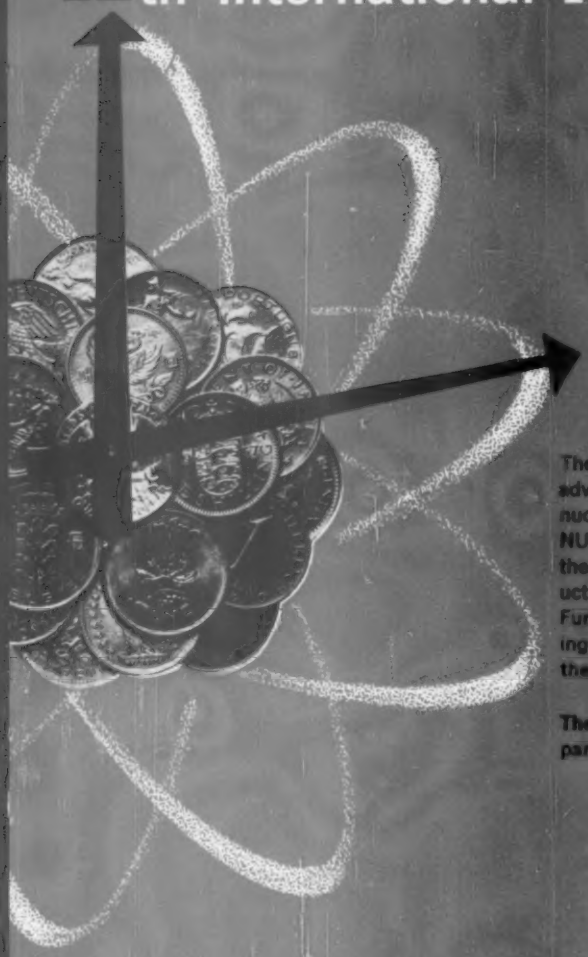
The type 1 cycles may be divided into those that derive power from a vapor in a Rankine cycle and those that employ a gas turbine in a Brayton cycle. The suspensions would have densities up to 10 lb/ft³ and pressures between 100 and 500 psi. Nuclear plants of this type (either Rankine or Brayton cycles) will derive the following benefits from using a gas suspension instead of a gas as the primary coolant:

- a higher heat-transfer film coefficient, which will permit a higher core-outlet coolant temperature for a specified maximum fuel temperature
- considerably larger heat removal from a given size reactor core both because of higher heat transport and higher heat transfer
- smaller primary-coolant loop
- lower primary coolant-loop pressure.

The effect of these improvements is illustrated by an analysis of the ther-

It's Time to Plan for the Nuclear Industry's Directory:

12th International NUCLEONICS BUYERS' GUIDE AND REFERENCE DATA ISSUE November 1961



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The Reference Data section — the extensive editorial portion of the issue — will consist of selected up-to-date engineering and scientific information of the type most frequently used by technical personnel in the nucleonics field. Included will be a cumulative index of contents of this year's and last year's Manuals. Constant referral to the Reference Data Manual by the readers adds to the year-long exposure of the entire November issue.

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NUCLEONICS

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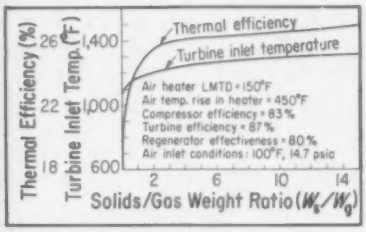

FIG. 5. THERMAL EFFICIENCY of type 1 cycle for nitrogen/graphite suspension

mal efficiency of a type 1 gas-turbine as a function of graphite loading in the primary loop with nitrogen as the carrier gas. Figure 5 gives the effect on gas-turbine thermal efficiency of the variations presented in Fig. 4 for inlet and outlet temperature as a function of graphite loading. Most of the increased efficiency is achieved at light solids loadings—below a solids-to-gas weight ratio of four. In the complete range of solids loading considered, the efficiency increased from 19% to 27%.

The development of efficient gas-suspension turbines and compressors would make possible type 2 cycles, in which the suspension acts as the thermodynamic working fluid as well as the reactor coolant. Although there is no experimental proof, one might predict that heat stored in the suspended solids will exert a strong influence upon gas temperature during expansion or compression by virtue of the very large particle-surface area. The result would be equivalent to a working fluid with unusually high specific-heat and low specific-heat ratio. Hence, this fluid should show smaller temperature changes during adiabatic compression or expansion; thus the ideal efficiency of the regenerative Brayton cycle could approach more closely the Carnot-cycle efficiency than with a pure-gas system. This increase in ideal cycle efficiency could compensate for the possible lower efficiencies of gas-suspension turbines and compressors.

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4. C. W. Albright et al. Pressure drop in flow of dense coal-air mixtures, *Ind. and Eng. Chem.* **43**, No. 8, 1837 (1951)

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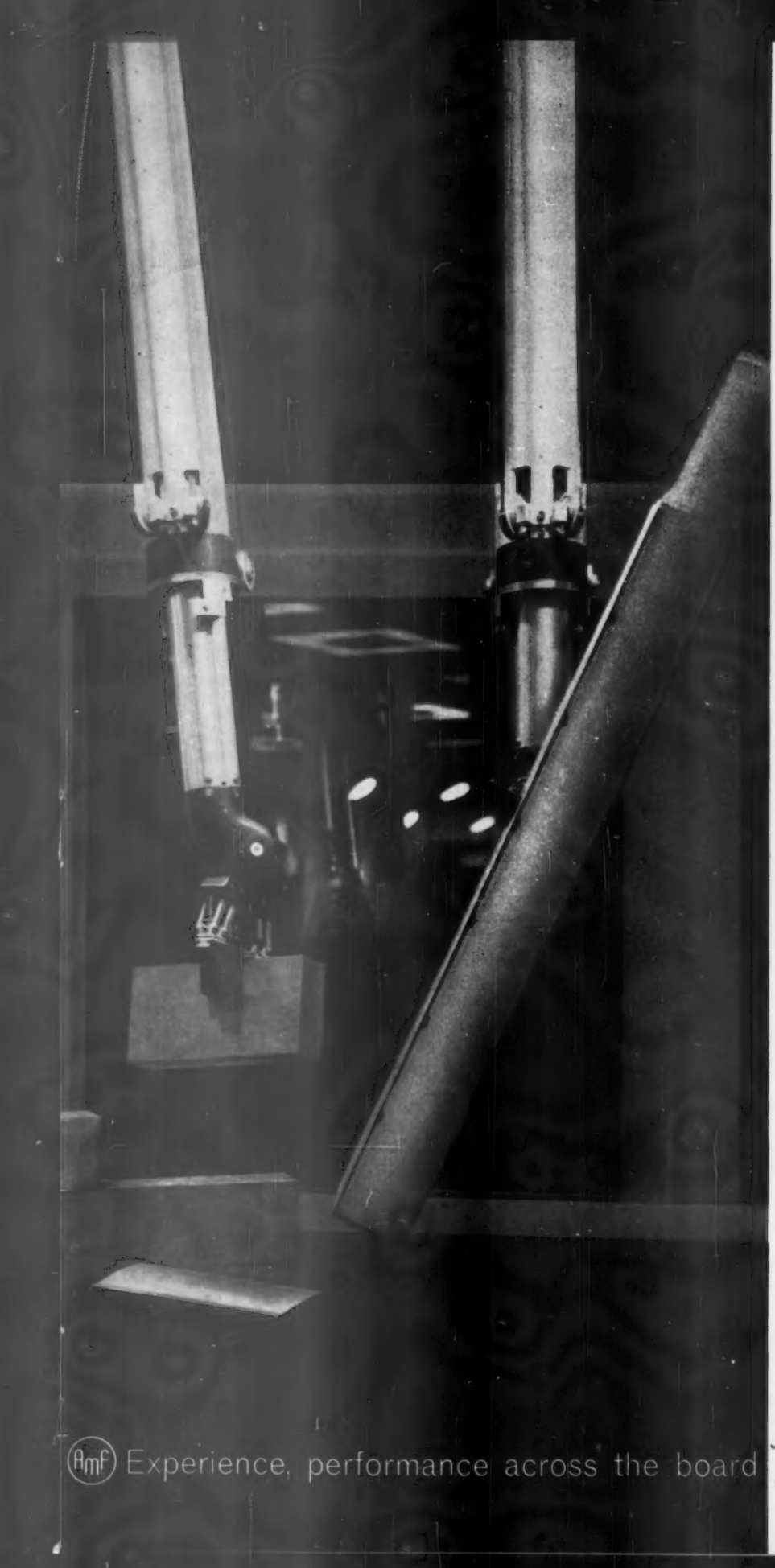

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Wantage School Teaches Radionuclide Applications

Ask a Briton who is a member of the Isotope Division of the Atomic Energy Research Establishment whether he is a crusader, and you will probably get the same answer that you would expect from his American counterpart: "Yes." On both sides of the ocean, users of radiation and radiotracers feel the same need to sell the world the benefits of radioactivity. One of the missionary efforts of AERE is the Isotope School at Wantage Radiation Laboratory. In 10 years of existence it has turned out more than 2,600 students from 70 nations. Included are chemists, doctors, physicists, biologists and engineers from universities, industry, hospitals and government.

Results are impressive; a 1958 questionnaire showed that 88% of the graduates were using radionuclides; more than 50 radionuclide courses are direct descendants of the Wantage one.

If you want to go to the school from London you can take a train ~50 miles straight west to Didcot, directly south of Oxford. A short drive along tree-lined roads takes you first to the town of Wantage with its statue of Alfred the Great in the town square, and then, a mile farther, to the abandoned World War II airfield that has become Wantage Radiation Laboratory. The school occupies a light and airy building in the style of a California ranch house. Director is Ronald A. Faires, who, with his associate B. H. Parks, has written a book called "Radioisotope Laboratory Techniques" (Pitman Publishing Corp., New York, 244 pp., $5.75).

The program, as indicated by our box, is based on a four-week "General Isotope Course" and reinforced with various more specialized courses according to demand. In 1960, for example, special courses were given for water chemists, directors and senior executives in industry, and senior trade-union officials. The basic course, which is given about four times a year, is intended for students at graduate level who wish to use radionuclides as tools in research or technology. Emphasis is on practical work, ~70% of the time being devoted to experiments (activation analysis, chromatography, gamma spectrometry) and the rest to lectures (nuclear physics, radiochemistry, measuring techniques, health physics).

Advanced courses call on facilities and personnel of both Wantage and nearby Harwell. For example the trade-union officials heard, in addition to Faires and Parks of the Isotope School, B. S. Smith, head of the Isotope Division, J. L. Putman, J. F. Cameron, S. Jefferson, H. Bowen and several others.

Curricula are designed to include both experiments that are carried out by all students and special topics chosen by the students themselves. Advanced radiochemists, for example, study such topics as isotope effects, radiotracers in electrochemistry, reactor chemistry, coincidence and anti-coincidence spectrometry and radioautography. Among the experiments designed for all of them to do are solubility measurements, exchange studies, standardizations and ion-exchange studies. Students in an advanced physics and measurements course study such matters as single-crystal and two-crystal scintillation counters, liquid scintillation, thermal-neutron-detection of sodium and manganese in solution (by beam attenuation and capture gamma rays), γ,n detection of beryllium and soil-moisture measurement by slowing of fast neutrons. Graduate analytical chemists learn such determinations as copper in aluminum and analysis for arsenic in hair using radiotracer methods.

Fees are a uniform £3/day ($8.40) for everything required at the school except board and room. Overseas students are warned to budget 25–30 shillings ($3.50–4.20) per day for meals and accommodation in the moderate-priced hotels of the neighborhood.

AERE Isotope School—Program of Courses for 1961

Date	Title
9 Jan.–3 Feb.	General Isotope Course
13–24 February	Radiation in Biology and Chemistry
10–28 April	Medical Course (followed by three weeks visiting hospitals)
1–19 May	Radioisotope Methods in Chemistry
29 May–2 June	Radiological Protection
12 June–7 July	General Isotope Course
10–21 July	Advanced Course in Physics and Measurements
10–28 July	World Health Organization Course: Public Health Aspects of Radiation Protection
24–28 July	Autoradiography for Biologists
18 Sept.–6 Oct.	Medical Course (followed by three weeks visiting hospitals)
16–20 October	Radioisotopes in Nondestructive Testing
30 Oct.–3 Nov.	Radiological Protection
13 Nov.–8 Dec.	General Isotope Course

How Does One Handle Soil Contamination?

In the unfortunate event that fallout or a reactor accident were to contaminate a farmer's fields—or, worse yet, a vast area of them—how would one grow crops that were not dangerously radioactive? Roy Overstreet, professor of soil chemistry at the University of California, and his associates have been conducting tracer experiments, mainly with strontium and cesium, to see.

Since not much is known about trace amounts of cesium and strontium in soil, basic studies deal with how these and other fallout nuclides are held in different soils and leached from them (*1–4*). For example, they contaminated different California soils with

Sr^{85} and tested the ability of ammonium-acetate and calcium-chloride solutions to leach out the strontium. Since leaching occurs readily, they conclude that contaminating strontium is held in forms that make it readily available to plants. Cesium appears to be held in two different ways so that trace concentrations behave differently from larger amounts. It is very tightly fixed by most soils so that it is only slightly available to plants.

Plant experiments determine how much of a radioactive nuclide is picked up from the soil in roots, stems and leaves, or how the ratio of two nuclides differ between soil and plant (*5*, *6*). An abundance of potassium, for example, suppresses the uptake of cesium in excised barley roots; abundances of sodium and lithium have essentially no effect.

One set of experiments (*2*) compared three methods for reducing strontium content in barley grown in previously contaminated soil. If you treat the contaminated soil with electrolytes (HCl and $FeCl_3$ are most effective) and then apply water, you can wash the strontium deep into the ground, but the method is forbiddingly expensive. If you put the contaminant deep in the test plot to simulate deep plowing, its uptake by barley roots is much less but still appreciable.

Only one method appears really useful: spread asphalt emulsion on the soil, allow it to harden, then chop it up and haul it away. You can take away as much as 97% of the contamination. Simply breaking up the crust and turning it under doesn't work; most of the strontium becomes available to the plants anyway.

This result suggests that the solution to the problem of soil contamination may be the entrapment of the fallout by physical or chemical means before it becomes mixed with the soil.

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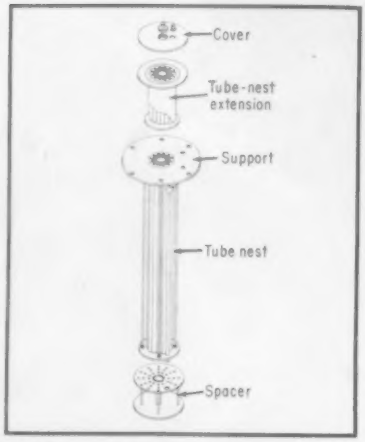
12,000-Curie Cs^{137} Research Irradiator at Georgia Tech

by RICHARD C. PALMER,
RANDALL W. CARTER
and WILLIAM VAN WILLIS,
Georgia Institute of Technology, Atlanta, Georgia

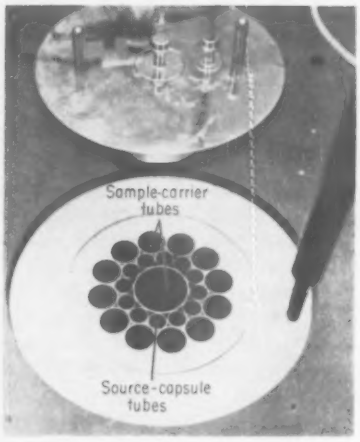
Although cesium irradiators are far rarer than their cobalt cousins, they have properties that may make them give comparable results. For example, the long cesium half-life should make capital investments nearly the same. In addition, attenuation of gammas from Ba^{137} (daughter of Cs^{137}) is greater than that of gammas from Co^{60}. In cesium irradiators bremsstrahlung should also contribute to dose rate. Because our 12,000-curie cesium irradiator is patterned after the Notre Dame Co^{60} one [NUCLEONICS **13**, No. 10, 74 (1955)], we hope to compare operating results.

* * *

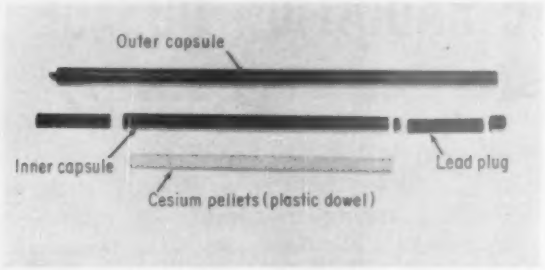
This work was sponsored by the Office of Isotope Development, U. S. AEC, under contract AT(38-1)-802.



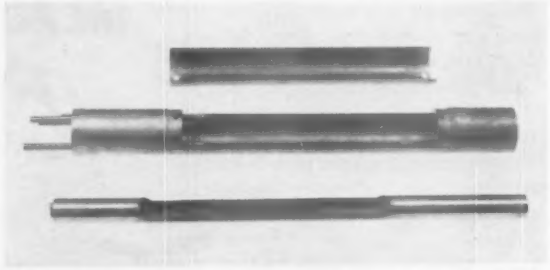
IRRADIATOR is held in 12.39-in.-i.d. stainless-steel pipe sunk 12 ft below floor. Top of 9-ft tube nest is supported by ½-in. brass plate; bottom by 3-ft spacer with perforated top so water can circulate. With 30-in. tube-nest extension one can process samples at table-top level



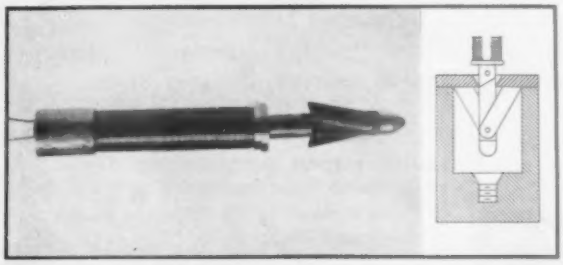
TOP OF TUBE NEST with cover plate removed shows holes into which sample carriers and source capsules go. Cover plate and tube nest are made from hard, drawn, seamless brass tubing. At right of picture is lifting mechanism that removes sample carriers remotely from irradiator



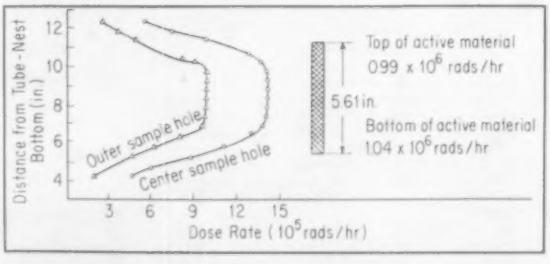
TWELVE SOURCE CAPSULES each hold ten pressed cesium pellets (represented above as plastic dowel) that have a total of 1,000 curies of Cs^{137} activity (with <3% Cs^{134}). Cesium pellets are enclosed in inner and outer stainless-steel capsules. 3.64-in. lead plugs seal each end of inner capsule. Inside irradiator tube nest, source capsules rest on 1-in. lead spacers beneath brass-rod shielding lengths



TWO SIZES OF SAMPLE CARRIERS made of soft brass fit into irradiator. One large carrier for center hole (center and top in picture) holds 1½-in.-i.d. container with 200-cm^3 sample. Twelve smaller sample carriers for outer holes (bottom in picture) hold standard 6-in. test tubes. Each carrier is shielded at top and bottom by 3-in. brass plug; each has machined top for lifting mechanism



LIFTING MECHANISM has 300-turn copper-wire solenoid around permeable steel-alloy core. Attached to brass extension are two steel-alloy leaves. To lift carriers one pushes extension into opening at carrier top. As leaves enter opening they close, popping open again inside cavity to grip carrier lip and lift carrier. When electricity passes through solenoid, leaves close and lifting mechanism can be withdrawn



DOSE-RATE DISTRIBUTION across vertical distance. Flat sections of curves indicate that in center hole sample ~3 in. long is subjected to homogeneous field and receives ~1.4 × 10^6 rads/hr; in outer holes samples homogeneous field receive ~1 × 10^6 rads/hr. Dosimetric measurements were made with a Fricke dosimeter that uses ferrous sulfate and measures the number of molecules oxidized to ferric ions

Instrumental Neutron Activation for Rapid, Economical Analysis

by VINCENT P. GUINN

Shell Development Company, Emeryville, California

Recent advances make it possible to perform many elemental analyses without chemical treatment by irradiating a sample with thermal or fast neutrons and observing energies and half-lives of decay gamma rays. With this rapid and comprehensive system of instrumental neutron activation one can accurately analyze samples in 15–30 min; in addition, the intense, energetic x-rays that are developed with a 3-Mev Van de Graaff accelerator allow one to use activation analysis with photoexcitation reactions for a number of additional elements and with photoneutron reactions for deuterium and beryllium.

The major advantage of the instrumental over the conventional, chemical-separation activation analysis is speed. This speed makes the instrumental neutron activation method a serious competitor of many well known chemical and spectroscopic methods even for concentrations well above trace levels to which conventional methods are easily applied. In this region the activation method is usually faster and has about the same accuracy as the older methods.

Two advances played an important role in developing this activation-analysis method: the commercial availability of (1) inexpensive positive-ion accelerators and (2) versatile and reliable multichannel pulse-height analyzers. Whereas most earlier work was carried out with million-dollar nuclear reactors, now a $20,000 accelerator enables one to do useful work in activation analysis (*1*). Whereas most earlier work involved chemical separation following activation and therefore took hours or days for analysis, the newer technique involves no separations and needs only minutes for analysis. In the author's opinion, these advances will result in the widespread use of activation analysis.

Available Neutron Sources

Neutron sources for activation analysis may be conveniently classified in three main types: small-, medium- and large-flux sources.

In the first type fall isotopic sources such as radium-beryllium, polonium-beryllium, plutonium-beryllium and antimony-beryllium (*2*). Although these sources are inexpensive (~$2,000) and portable, they have the major disadvantage of producing only $\sim 10^5$ thermal neutrons/cm²/sec (*3*, *4*).

The medium-flux sources—small Van de Graaff (*5*) and Cockcroft-Walton (*6*) deuteron accelerators that cost ~$20,000—can produce $\sim 10^8$-n/cm²/sec fluxes of 14-Mev neutrons and, after moderation, thermal neutrons. The cost of the accelerators is small relative to other particle accelerators because the $H^3(d,n)He^4$ reaction does not require a large bombardment energy—in fact the reaction has its maximum cross section at ~0.1 Mev.

For certain applications one needs the 10^{11}–10^{12}-n/cm²/sec thermal-neutron flux available only from small research reactors such as the $150,000, 10–100 kw General Atomic Triga.

Although as one goes to higher flux sources, the cost per neutron drops sharply, the capital investment rises considerably. It seems, therefore, that small deuteron accelerators provide an excellent compromise since with their flux one can determine many elements at concentrations as small as 1–10 ppm (parts per million).

Thermal-Neutron Activation

For the past four years the author's group has been developing a system of instrumental thermal-neutron activation analysis using the 3-Mev Van de Graaff electron accelerator [usually used for radiation chemistry (*7*)] and a 6-in. cube of beryllium as a neutron source. This method has been in semi-routine use for the past two years 40 hr a week; the Van de Graaff operates on evening shift for the work (*8*).

In this system, 3-Mev electrons strike a gold target where they generate a very large intensity of x-rays (bremsstrahlung) (*9*). These x-rays in turn bombard the beryllium block and produce neutrons from the $Be^9(\gamma,n)2He^4$ reaction. These neutrons are slowed down to thermal energies by collisions with beryllium nuclei and with hydrogen nuclei in the surrounding moderator tank of terphenyl. In the sample ports—vertical tubes mounted next to the beryllium block—the thermal-neutron flux is close to 10^8 n/cm²/sec. Each of the eight ports can hold as many as three 1-oz polyethylene sample bottles. By using large (25-gm) samples one partially compensates for the moderate flux level and thereby increases the sensitivity of the system.

A 3-in. well-type NaI (Tl) scintillation counter and a Penco 100-channel pulse-height analyzer with data printer and strip-chart recorder measures the gamma-ray spectrum of each activated sample.

An initial survey of a large number of elements soon showed that at the 10^8-n/cm²/sec flux one could achieve quite useful sensitivities of detection for 26 elements (Table 1). In fact, for quite a number of elements, one could get sensitivities in the parts-per-million range. The sensitivities in the table are based on irradiation times of 2 hr or less, but one should note that equally good sensitivities can be reached in much shorter activation times if the half-life of the radionuclide formed is very short. The elements, hydrogen, carbon, nitrogen, oxygen, fluorine, sulfur, phosphorus, silicon and iron are not in Table 1 because they are not detected with thermal neutrons. This is fortunate since if they were detected, the major constituents of aqueous, organic, mineral and alloy samples would introduce interferences in determining minor components. A number of these missing elements can, however, be determined quite well with fast neutrons.

Speed of method. The speed of the process enables one to use many induced activities of very short half-life that decay too rapidly to allow time for chemical separations. With such short half-lives one very quickly approaches saturation or steady-state

TABLE 1—Sensitivities of Detection

Limit of detection (ppm)	*Elements*
0.1–1	V, Co, Br, Ag, In, I, Re, Au, Mn
1–10	Na, Al, Cl, Cu, As, Sb, W
10–50	Ti, Mo, Ru, Sn, Pt
50–100	Mg
100–400	K, Ca, Ni, Zn

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Neutron Activation Analysis

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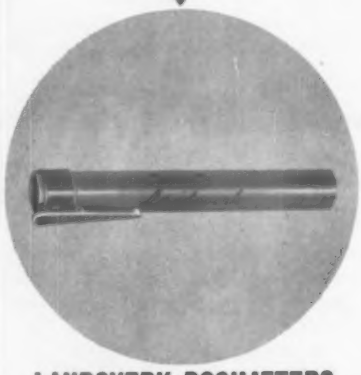
activity in a sample. Thus one reaches a level of one half the saturation activity in an irradiation time equal to the half-life of the radionuclide being formed; three fourths in two half-lives; seven eighths in three half-lives, and so on. For this reason and because longer irradiations increase interferences from longer-lived activities it is seldom desirable to activate for longer than a few half-lives of the nuclide. Many of the activities in the instrumental method have half-lives in the range of minutes (Table 2). Even for the longer-lived nuclides the average activation time for each sample is short if a number of samples are activated simultaneously. For example, if a number of samples are to be analyzed for arsenic, as many as 24 samples can be activated simultaneously. Although for maximum sensitivity a 2-hr activation would be employed, the average time spent on activation for each sample is only 120 min divided by 24, or ~5 min per sample. In addition to the activation time of 5 min, one spends ~5 min to determine the gamma-ray spectrum of the activated sample and an additional 5 min to calculate the photopeak area. Thus a total analysis time of ~15 min is fairly typical in this method for one constituent (*10*). The amounts of other elements that might show up in the gamma-ray spectrum may be computed in perhaps 5 additional minutes each.

Interferences of one activity with another can be eliminated or reduced to a minimum in most cases by choosing suitable activation times and decay periods before counting.

At levels well above the limiting sensitivities and in the absence of serious interference the precision of the method for one determination is

TABLE 2—Nuclides in Analysis

Range of half-lives			
< 10 min	*10–60 min*	*hours*	*days*
9.5—Mg^{27}	37—Cl^{38}	15—Na^{24}	1.1—As^{76}
2.3—Al^{28}	10—Co^{60m}	12—K^{42}	1.0—W^{187}
8.7—Ca^{49}	18—Br^{80}	2.6—Mn^{56}	2.7—Au^{198}
5.8—Ti^{51}	15—Mo^{101}	2.6—Ni^{65}	
3.8—V^{52}	54—In^{116}	14—Zn^{69m}	
5.1—Cu^{66}	25—I^{128}	4.5—Ru^{105}	
2.3—Ag^{108}	20—Re^{186m}		
9.5—Sn^{125}			
3.5—Sb^{122m}			



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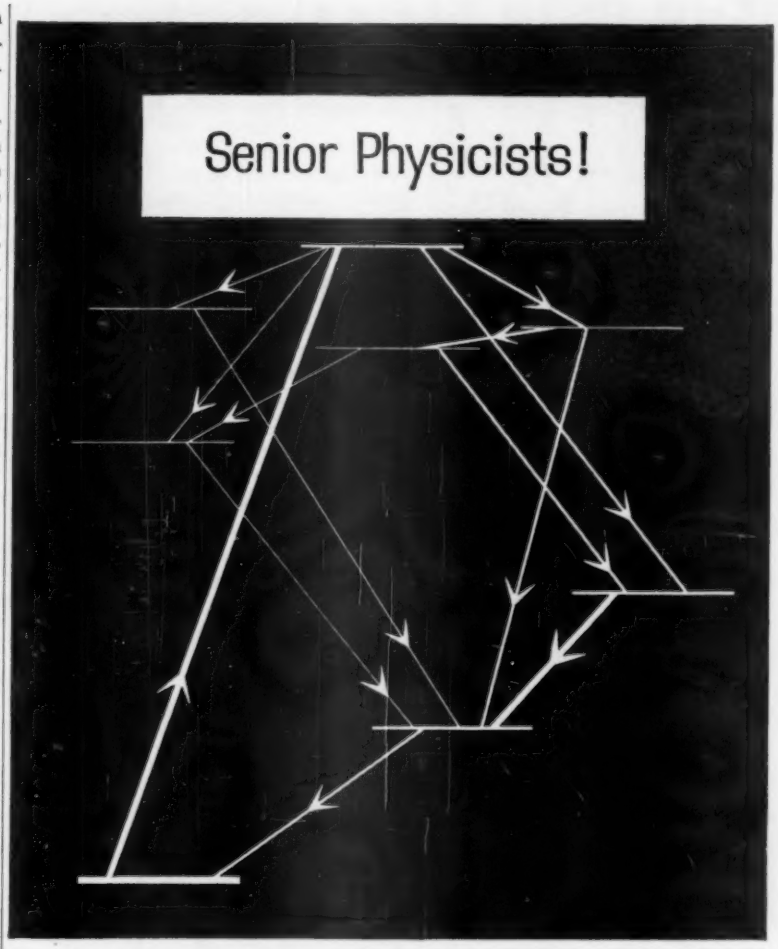
±2% of the value. Also, at such high levels even short (5–10 min) activations are sufficient for the longer-lived nuclides shown in Table 2.

A very useful feature of the instrumental method is the speed with which a suitable activation-analysis procedure can be worked out for relatively little known elements (*10*). A well qualified analytical chemist, not already familiar with an element, would take many days, weeks or even months to investigate the literature on the chemistry of the element and try out various reactions in developing a good analytical method. On the other hand, the author needs only about an hour to develop a neutron activation method for an unfamiliar element: a brief glance at the "General Electric Chart of the Nuclides" and the "Seaborg Table of Isotopes," a short calculation of estimated activity, a few minutes activation of a pure compound of the element, a few minutes counting with the gamma-ray spectrometer and a few further calculations are all that are needed. From this information one can get the experimental gamma-ray spectrum of the activated element, the half-life of its principal nuclide; data for calculating the ultimate sensitivity at 10^8 n/cm²/sec and an idea of which of the more common elements might interfere with the determination of the element.

Although the purely instrumental method has many advantages of speed over other methods, it is not suitable in all cases. In some complex samples interferences exist that require chemical separations (*11–15*). Meinke has recently developed very rapid chemical separation techniques that allow one to use even fairly short-lived activities with advantages in freedom from interferences obtained by the separations (*16*).

Fast-Neutron Activation

The 14-Mev fast neutrons generated in deuteron accelerators activate many elements that are not suitably activated by thermal neutrons. For example, fast-neutron activations have been used for oxygen (*17*), nitrogen, phosphorus, fluorine, silicon and iron (*18*). For many of these elements, instrumental activation analysis with fast neutrons gives sensitivities of 10–100 ppm. Although the field of fast-neutron activation analysis is not yet as completely developed as that with thermal neutrons, progress is very rapid and the method offers promise.



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Neutron Activation Analysis

This article starts on page 81

Photoexcitation Analysis

The intense x-ray flux suggested the possibility of using photoexcitation reactions in activation analysis. Experiments soon revealed that some 16 elements will produce detectable amounts of induced radioactivity (*19, 20*). The activities produced are all excited states of stable nuclides that decay by gamma emission with measurable half-lives. Generally speaking, although the sensitivities attainable in the photoexcitation technique are not as good as those from neutron activation, the method is sometimes a useful supplement if serious interferences occur in the neutron activation method.

The author also used the intense x-ray flux of the Van de Graaff for detecting deuterium and beryllium down to parts-per-million levels with the $H^3(\gamma,n)H^1$ and $Be^9(\gamma,n)2He^4$ photoneutron reactions. For detection, he used a detection element such as manganese or iodine that is readily neutron activated by the photoneutrons produced.

* * *

This article is based on a paper presented at the 1960 Annual Conference of the Atomic Industrial Forum in San Francisco, California; it subsequently appeared in the Proceedings of the conference (pages 308-314).

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Oak Ridge Fusion Group Lengthens Containment Time in DCX

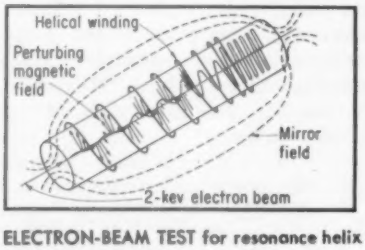
Using the DCX (Direct Current Experiment) [NU **18,** No. 3, 138 (1960)] members of the Oak Ridge Thermonuclear Division have recently increased the containment time for rapidly circulating hydrogen ions at moderate densities (10^7 protons/cm^3) from a few thousandths of a second to ~3 sec. In these experiments a plasma ring of 300-kev protons was formed concentric with the magnetic axis without the carbon arc used with 600-kev diatomic hydrogen ions in the DCX. This was possible because collisions occur between the ions and residual gas molecules. C. F. Barnett, director of the group, reports that in this method the protons "are well trapped. An encouraging aspect is that the experiments disclose reason for expecting even longer residence times. At these rather modest densities of trapped ions, no loss mechanisms have been observed in our containment scheme other than those depending upon the presence of residual gas." In the future the group "will undertake to increase the density of stored ions, to study the extent of orbital disorganization, and to investigate the homogeneity of the ion distribution." (Based on article by C. F. Barnett, et al., *Phys. Rev. Letters* **6,** 589, June 1, 1961.)

Resonance Helix Confines Particles in Magnetic Mirror

A new idea for injecting and trapping energetic charged particles in magnetic-mirror geometries may confine particles for lengths of time interesting to Project Sherwood. In this method, originally proposed by the Russians (*1*), modified by Richard C. Wingerson of MIT (*2*) and experimented on at the Los Alamos Scientific Laboratory (*3*), a 100-gauss magnetic field between the mirrors is weakly modified by a field that is both perpendicular to the mirror-field axis and rotates spatially around it (see figure). This perturbing field is formed by a variable-pitch helix that has its axis coincident with the axis of the mirror field. If a charged particle is injected parallel to the mirror-field axis, a resonance condition exists between (a) the longitudinal velocity of the particle, (b) the strength of the mirror field and (c) the period of the modulating magnetic field. While this resonance condition exists, longitudinal energy is transferred to perpendicular energy. If the perpendicular energy is not transferred rapidly back into longitudinal energy on subsequent particle trips, particles will be trapped.

At Los Alamos theoretical calculations have been made of resonance conditions for a simplified model. In addition, two types of electron experiments have tested the method. In the first, with a glass plate coated with scintillating material and aluminized to make it conducting, one can determine whether an injected electron beam obeys the resonance condition by observing its rotation about the center line of the apparatus. In the second, one measures with a current-collecting cap the current transmitted down the tube and the energy distribution of the electron beam parallel to the magnetic field. From these experiments the Los Alamos group finds that the resonance condition is verified and that three quarters of the 2-kev initially injected beam energy is transferred into perpendicular energy. Although preliminary, these measurements indicate some electron confinement.

Work now being done at Los Alamos is aimed at finding whether the perturbing field needed to inject and trap energetic particles breaks down the containment properties of mirror machines to such an extent that the system becomes impractical. Results will be announced at the IAEA conference on Plasma Physics and Controlled Nuclear Fusion Research in Salzburg, Austria, Sept. 4–8th.



ELECTRON-BEAM TEST for resonance helix

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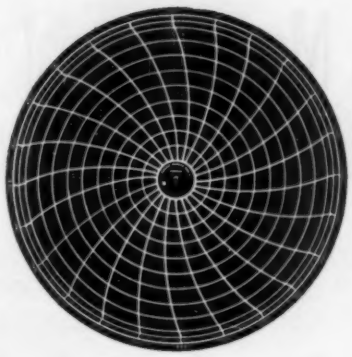
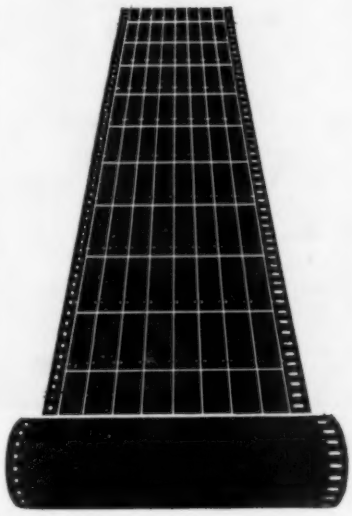
1. K. D. Sinelnikov et al., *J. Tech. Phys.* USSR **30,** 249 (1960)
2. R. C. Wingerson, *Phys. Rev. Letters* **6,** 446 (May 1, 1961)
3. Controlled thermonuclear processes, LAMS-2529





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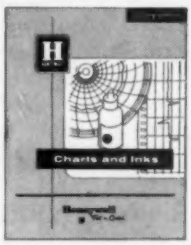

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Nuclear Power in Space

DEAR SIR:

We noted with interest the comments in the April issue of NUCLEONICS that SNAP-2 had completed the longest sustained run for a high temperature reactor (100 hr at 1,200°F).

You may be interested to know that Aerojet-General Nucleonics' GCRE has completed two 100-hr full-power runs for experimental purposes and, on April 6th, completed a 116-hr run at full power. Full power at GCRE is ~2.2 Mw(t) and is defined as that power level where the coolant effluent from the hottest fuel-element channel(s) is 1,300°F.

This normally corresponds to a mixed mean coolant effluent temperature for the entire reactor of 1,150–1,200°F.

—LAIRD DURHAM
Aerojet-General Corp.
San Ramon, Calif.

On Radionuclide Heat Sources

DEAR SIR:

In the April 1961 issue of NUCLEONICS (ed. note: *Radionuclide Power for Space Missions*, by Douglas G. Harvey and Jerome G. Morse) I have found some numerical quantities that I am unable to confirm.

Table 1 on page 70 furnishes for different radionuclides the quantities: watts/cm³, gm/cm³ and curies/watt. By a simple combination of these three parameters, one can calculate the number of curies per gram for the four emitters: Ce^{144}—250, Pm^{147}—450, Cs^{137}—104, Sr^{90}—17. Thus one has the number of curies of emission per gram of a chemical compound containing the radionuclide; if one knows the chemical formula it is easy to calculate the number of curies of emission per gram of the emitting substance. One finds: Ce^{144}—305, Pm^{147}—535, Cs^{137}—128, Sr^{90}—36.

These last figures, however, differ appreciably from those furnished by the classic formula: curies/gm = 355,000/AT (A is atomic mass in grams; T is half-life in years.)

One then gets the following table:

	A	T	curies/gm
Ce	144	0.79	3,120
Pm	147	2.26	1,060
Cs	137	33.00	78
Sr	90	25.00	156

How do you explain these differences? Is it possible that the chemical compositions you are considering contain isotopes of the radionuclide considered which would explain why your numbers are less than the theoretical numbers obtained using the formula above? (Even these considerations, can't justify the case of cesium.)

—G. PARREINS
Commissariat a l'Energie Atomique
Centre d'Etudes Nucleaires de Saclay
Gif-sur-Yvette, France

The author answers . . .

DEAR SIR:

We have reviewed Mr. G. Parreins's critique of our article in the April issue of NUCLEONICS and have detected an error in the values given in Table 1, page 70. The thermal power for Cs^{137} Cl should read 0.27 watts/cm³. In Mr. Parreins's analysis this would give a value of 26.6 curies/gm for Cs^{137}.

Using this corrected value for cesium and the other values quoted, one finds that the obtainable specific activities for the isotopes in question are considerably below the theoretical values. Impurities (usually sister isotopes) in the initial fission-product waste and impurities introduced as carriers in the separation procedure cause this discrepancy.

Our apologies for this incorrect data.

—DOUGLAS G. HARVEY
—JEROME G. MORSE
The Martin Company
Baltimore, Md.

Keeping Up with Nuclear Literature

DEAR SIR:

In your Spring Book Roundup in the May 1961 issue you devoted considerable space to the problem of keeping up with the nuclear literature. We were astonished to find no mention of *Chemical Abstracts* as a source for keeping abreast of nuclear literature, as we regularly publish in Section 3A, Nuclear Phenomena, and in related sections, abstracts of nuclear literature (of chemical interest) published in all languages throughout the world. This includes coverage of some 1,500 Russian journals, the most complete collection in this country.

—B. SCHLESSINGER
—R. SALVADOR
The Chemical Abstracts Service
Ohio State University
Columbus 10, Ohio

NUCLEAR BOOKSHELF

Radiation Damage in Solids

By DOUGLAS S. BILLINGTON and JAMES H. CRAWFORD (Princeton University Press, Princeton, N. Y., 1961, $12.50, xi + 450 pages)

Reviewed by MICHAEL W. THOMPSON, Metallurgy Div., AERE, Harwell, England

This book should be welcomed both by existing and intending specialists in the field of radiation damage. It is not a work from which the casual reader could quickly gain an over-all picture of the field, but rather a reference book with sufficient introductory material to provide the newcomer with a sound basis for research. The authors have been actively interested in this subject since its very early days and it would be hard to imagine a team better qualified to treat it. The style of writing is attractive, the subject matter well arranged and the mathematical arguments presented in a simple manner without unnecessary sophistication.

Such a comprehensive view of the subject at this detailed level has not previously been attempted. The first few chapters deal with general aspects such as the collision processes leading to damage, the nature and basic properties of crystal defects and a comparison of radiation sources. The last of these three chapters contains a valuable collection of data on damage rates and charged-particle penetration and is typical of the way in which the experimenter's needs have been catered to throughout. Subsequent chapters deal with damage in each main class of crystalline solid. In these chapters the detailed presentation and critical assessment of experimental data makes each one at least equivalent to a review article. Although the subject is treated from the standpoint of solid-state physics, the authors have emphasized the importance of radiation damage in nuclear technology in the last two chapters on graphite and uranium.

It seems inevitable that in a book that deals with a developing field of research, some of the material will become dated in the interval between writing and publication. It is not surprising therefore that new discoveries and techniques—for instance the importance of point defect clustering shown recently by electron microscopy—have resulted in certain shifts of emphasis. In general, however, these have affected the interpretations to a limited extent and the basic value of the book remains undiminished.

Fast Reactor Cross Sections—A Study Leading to a 16 Group Set

By S. YIFTAH, D. OKRENT and P. A. MOLDAUER (Pergamon Press, New York, 1960, $5.00, 130 pages)

Reviewed by GEORGE E. HANSEN, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

This well written monograph sets down in a concise fashion those neutron interactions of primary importance in fast reactors, the corresponding cross-section data that are available for the more prevalent fast-reactor materials, the reduction of these data to a multigroup form suitable for reactor computation and a comparison of computed and experimental values pertaining to critical sizes and neutron-flux spectra of selected fast-neutron critical assemblies.

Because of gaps and apparent inconsistencies in the cross-section data (summarized in Chapter 7), some guidance is needed for the reduction to multigroup form; the authors illustrate the application of nuclear models for this purpose and special detail is given for inelastic scattering. As an understandable ground rule for their study, the authors refrain from using integral data for additional guidance. I object, however, to the rationalization in the concluding sentence of the book: "Hence, the procedure employed only too often in the past, of adjusting one or more parameters to fit a limited range of critical experiments, will be useful over the range covered, but may lead to major errors upon application to a different set of circumstances." The implication seems to be that guidance by integral data may be worse than no guidance at all.

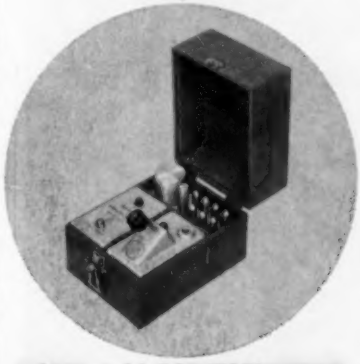
The authors have succeeded very well in presenting their study and the monograph should prove valuable to those interested in fast or intermediate reactors and those engaged in finding neutron-cross-section or integral data.

Modern Nuclear Technology

Edited by MARK M. MILLS, ARTHUR T. BIEHL and ROBERT MAINHARDT (McGraw-Hill Book Co., New York, 1960, $9.50, ix + 336 pages)

Reviewed by JOHN R. MENKE, Nuclear Development Corp. of America, White Plains, N. Y.

There has been a growing need in nuclear literature for a text aimed at the multitude of semiscientific personnel in the nuclear and allied industries



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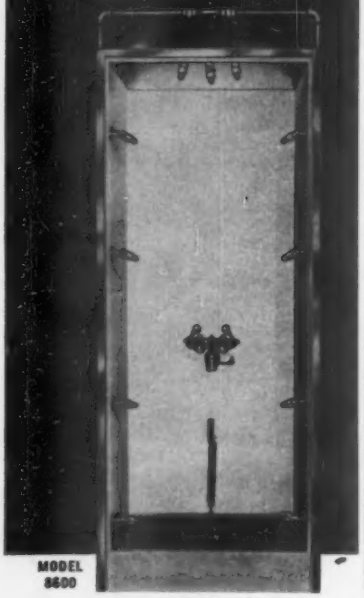

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who do not work directly on technical problems but have an influence on the direction to be taken by many phases of this diversified field. "Modern Nuclear Technology" essentially fills this gap. Management and nonnuclear technical personnel should find it both informative and interesting.

I have the following four specific criticisms of the contents of the book.

First, the section on economics is concerned primarily with the detail constituents of nuclear-power cost but does not describe adequately the close connection between the various financing schemes and the choice of reactor type and power-conversion equipment.

Second, three power-reactor types are discussed in detail in Part II, leaving the impression that there are no serious contenders. The boiling-water reactor is conspicuous by its absence.

Third, the impact of the availability of government-owned enriched uranium on the power-reactor phase of the industry does not come through. The method of handling the procurement of enriched uranium in an otherwise "commercial" industry has been under active debate for some time and is of considerable interest to organizations contemplating procurement of reactors.

Fourth, the future of nuclear energy, which is a major concern to company management, is rather brief. A prognostication of where we go from here, possibly written by the editors of NUCLEONICS, would have added some interesting points for discussion.

In conclusion, McGraw-Hill is to be congratulated for making available a book which is, in general, up to date in a very rapidly advancing field. It is only in the discussion of specific reactors that the time span between the lectures (1956 and 1957) and the publishing date (1960) becomes apparent.

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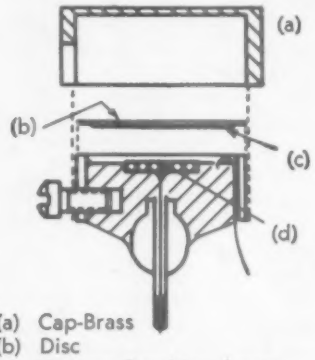

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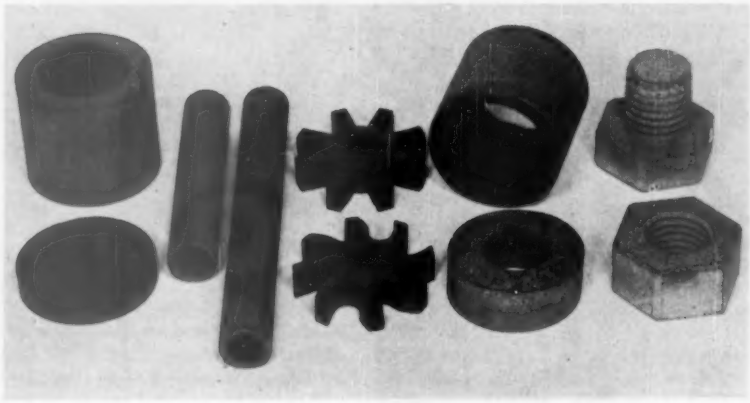


Boron Silicide—A New High-Temperature Material

Two well defined compounds—tetraboron silicide (B_4Si) and hexaboron silicide (B_6Si)—developed by Allis Chalmers, have high-temperature properties that make them excellent for reactor work. The compounds, containing 70% and 60% boron, respectively, not only have low densities (bulk density 0.4–0.7 gm/cm³) and good thermal-shock resistance but also show for extended periods outstanding oxidation resistance to temperatures up to 1,400°C in air. Consequently, they can be incorporated into steels for reactor control rods, encapsulated and used as burnable poisons or used in gas-cooled reactors where temperatures exceed ~594°C—the limit for boron carbide in oxidizing atmospheres.

Most boron-based solids corrode in air at about 800°C because atmospheric oxygen attacks the solids and forms volatile boric acid. Boron silicide, on the other hand, resists oxidation because it forms a protective boron-silicon-oxygen coating at temperatures above 700°C.

The excellent thermal-shock resistance of the compounds is partially due to their small thermal expansion. For example, oxide-bonded B_4Si and B_6Si bodies ($2.5 \times 2.5 \times 0.3$ cm) have been cycled from 1,095 to 25°C air blasts repeatedly without cracking. These bodies have also been quenched in water from 1,095°C without shattering.

Allis Chalmers's microhardness measurements on B_4Si show an average Knoop (100-gm load) hardness of 2,400. For B_6Si they get hardness values of 1,900–2,400.

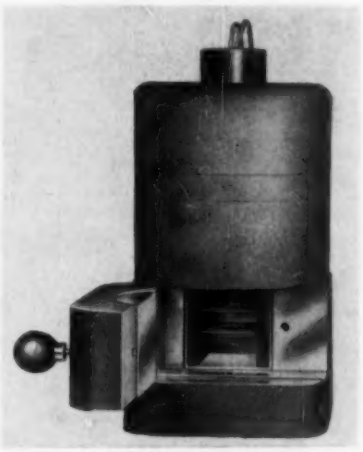
Both boron-silicide compounds are produced as black, free-flowing microcrystals of 70 microns or finer. The powder can be fabricated by conventional metallurgical and ceramic techniques: by oxide-bonding, self-bonding or hot-pressing. Components made from the compounds are shown in the figure. Recently, Allis Chalmers has developed a spray technique for applying these two boron-silicide compounds to parts that must be resistant to oxidation. For instance, the company claims that with the spray technique both graphite and molybdenum can be used structurally in such areas as air-cooled reactors which were previously forbidden to the metals.

The spray process is two fold. First the object to be coated is sprayed by a plasma jet device with about 0.004 in. of the boron-silicide material. The object is then heat treated.

(Article partly based on a paper by Ervin Colton, Research Division, Allis Chalmers Manufacturing Co.)

Resistance temperature sensor, Model 177A, for industrial applications involving radiation. Designed to measure temperatures in −70°–+300°C range, sensor withstands 500-rads/hr dose rate, 1 Mev average. Time constant is <5 sec for 63.2% of total resistance change when probe is plunged from room temperature air into hot water.—Rosemount Engineering Co., 4900 W. 78th St., Minneapolis 24, Minn.

Rate control. Digital comparator accurately controls speed, flow rate and pressure and provides formula control in multiple-component blending systems. A form of beat-frequency generator, the comparator delivers a series of pulses that cause a correction proportional to the error in the system.—Jordan Controls, Inc., 3235 W. Hampton Ave., Milwaukee 9, Wis.

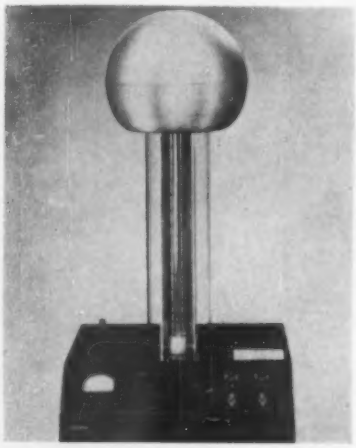


Counting shield. Model A-500 (above) shields the counting enclosure with 2½ in. of iron on all sides—the equivalent of 1.85 in. of lead. Enclosure is lined with ⅛ in. of aluminum. Shield adapts to scintillation-well, scintillation-planchet, flow-proportional and G-M counting.—Hamner Electronics Co., P. O. Box 531, Princeton, N. J.

Sanolin disposable sheeting is double faced to absorb radioactive drippings and keep them from penetrating work surfaces. Absorbing front surface is cellulose; repellent back is waterproof plastic. Sanolin comes in sheets from 13 × 19 in. to 40 × 90 in.—B. H. Jordan Co., 64 E. 8th St., New York 3, N. Y.

(Continued)

Automatic sample changer. SC-100 Multi-Matic Sample Changer (above), small enough for desk-top use, accommodates fifty samples in sizes up to 2 in. In contrast to previous stack changers, this one transports samples with a horizontal drive that makes samples instantly accessible.—Tracerlab, 1601 Trapelo Rd., Waltham 54, Mass.



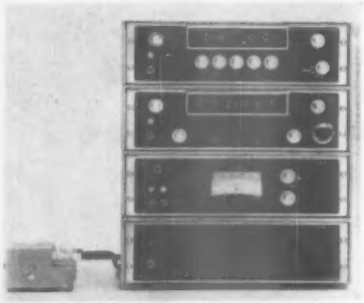
Generator and particle accelerator. Rayotron, a half-million-volt electrostatic generator combined with a high-energy particle accelerator, generates intense x-rays (above). As a generator, Rayotron is a self-contained Van de Graaff-type unit able to sustain a current of 20–30 μa.—Atomic Laboratories, Inc., 3086 Claremont Ave., Berkeley 5, Calif.

Semiconductor neutron detector. This solid-state neutron-sensitive ionization chamber with mμsec response and low gamma sensitivity operates at 25 v. It comes in 5 × 5-mm or 10 × 10-mm sizes with uranium, boron, lithium or hydrogenous material coatings.—Solid State Radiations, Inc., 9926 W. Jefferson Blvd., Culver City, Calif.

All-metal insulation for EGCR. 50,000 lb of stainless steel will insulate from heat the walls of the Oak Ridge Experimental Gas-Cooled Reactor. The insulation is "sandwich-like" with thin strips of corrugated stainless steel as "meat" and outer "bread" layers of noncorrugated steel.—Solar Aircraft Co., 200 Pacific Highway, San Diego 12, Calif.

More intense X-ray beam. For nondestructive industrial testing a high powered X-ray tube has been developed with a tiny (0.012 in. wide), concentrated focal spot. Since the angles of the x-ray striking an object are reduced, the image sharpness and intensity are increased and objects 1/500 in. wide can be examined. The tube can be used on the assembly line for continuous inspection of dense materials; tube is attached to a TV monitor (above) for viewing.—Picker X-Ray Corp., White Plains, N. Y.

Robot-vise positioner (above) has one to three arms, each with a machinist's clamp on the end that can be adjusted to any position and will hold a weight of 10 lb. The flexible arms move in three dimensions and the whole assembly rotates around three axes.—Norman Epstein, R. D. 2, Carmel, N. Y.



Four chasses measure activity. Available individually or in a single integrated unit, Logic 801 (above), the chasses are a preamplifier, high-voltage supply, scaler and timer. These chasses along with a cooling base make up Logic-802 unit for G-M counting or proportional and scintillation counting with integral pulse-height analysis.—Nuclear-Chicago Corp., 359 E. Howard Ave., Des Plaines, Ill.

Automatic pyrometer (above) measures and controls continuously temperatures up to 10,000° C; it records changes to less than one degree. A standard lamp calibrates the device.—Atomics International, P. O. Box 309, Canoga Park, Calif.

Pico-ammeter. High-gain, feedback electrometer has accuracy better than 3% of full-scale at all outputs. Range is 10^{-12}–10^{-3} amp and speed of response is less than 1 msec to 64% of final value at 10^{-9}–10^{-3} amp.—General Electric Co., Schenectady 5, N. Y.

Industrial x-ray film. Type M, single-coated code 5534 is available in 14 × 17, 8 × 10 and 5 × 7 in. sizes. Film has regular Type M emulsion coated on one side of film base and black gelatin coating on other side. Exposure speed is ½ that of double-coated Type M film.—Eastman Kodak Co., Rochester 4, N. Y.

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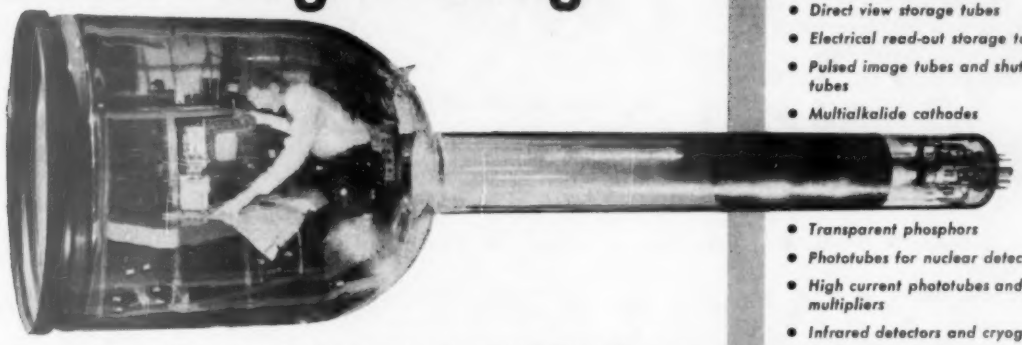

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If you design electronic systems requiring special purpose vacuum tubes, a new ITT-developed slide chart, "Phosphors and Photocathode Characteristics", will be of interest and value. Send requests to Component Sales.

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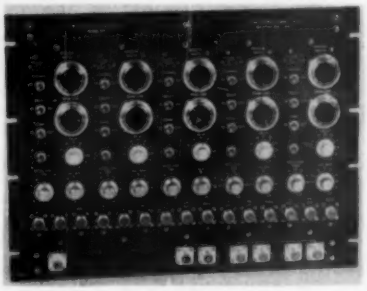
Steel for Antarctic reactor. Lukens is providing 38 steel half shells (above), eight heads and seven flat plates for cladding the Antarctic power reactor in McMurdo Sound. Twenty tons of special-duty steel cladding will be shipped to the South Pole in November. —Lukens Steel Co., Coatesville, Pa.

Field-effect transistor. About ten times more resistant to radiation than conventional transistors, this silicon field-effect transistor combines the advantages of the thermionic pentode and conventional transistor. It is a three-terminal amplifying device.—Crystalonics, Inc., Cambridge, Mass.

Testing plutonium hardness. Designed for glove-box operation, testing machine for plutonium hardness has operating controls, 1,800°F electric furnace, indexing compound and microscope.—Riehle Testing Machine Div., American Machine and Metals, East Moline, Ill.



Multiple coincidence unit. Based on a design by Robert L. Chase of Brookhaven, the Model 801 (above) accepts up to five input signals and delivers three simultaneous output signals so that three aspects of a decay scheme can be studied at once. Coincidence resolving time is adjustable from 0 to 180 mμsec.—Cosmic Radiation Labs., Bellport, N. Y.

Neutron ionization chamber. Similar to that developed for the Fermi Reactor in Chicago, this monitoring probe (above) will detect thermal neutrons in the 250–2.5 × 10^{10} n/cm²/sec range in a gamma field of 15,000 r/hr. Chamber operates up to 550°F.—Lionel Electronic Laboratories, 1226 Flushing Ave., Brooklyn 37, N. Y.

1% zirconium-niobium tubing. Developed for fuel-element cladding and heat-exchange tubing in reactors, material retains pure niobium (columbium) low nuclear cross section and excellent resistance to corrosion but extends the application of the tubing to higher temperatures.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

(*Continued*)

6-lb welding gun will be used at Indian Point to weld condenser tubes to tube sheets. Gun has successfully welded 30 tons of tubes to sheets in N. S. *Savannah*. It makes a permanent joint with a rotating tungsten electrode in an inert-gas atmosphere; no filler metal is needed and the tensile weld strength is large.—Revere Copper and Brass Inc., 230 Park Ave., New York 17, N. Y.

Four series of capacitors. Low-inductance storage capacitors with power ratings up to 20,000 Mw come in series NRG-114, NRG-200, NRG-300 and NRG XN-249. Units range from 20 to 125 kv d-c in capacitances from 0.1 to 10 mfd with 80—7,200 watt-sec ratings and inductances from 0.005 to 0.08 mh.—Cornell-Dubilier Electronics Div., Federal Pacific Electric Co., 333 Hamilton Blvd., S. Plainfield, N. J.

Radiation films for students. "Nuclear Radiation," a series of seven films, some in black and white, some in color, explain on the high-school level, types of radiation, tell how each is detected and used and about radiation damage and fall out.—Cenco Educational Films, 1700 Irving Park Rd., Chicago 13, Ill.

30-lb zinc crystals. Single zinc crystals, 5 in. in diameter, are available for neutron diffraction work. The crystals are 99.999% pure zinc.—Semi-Elements, Inc., Saxonburg Blvd., Saxonburg, Pa.

Temperature transducers. Specifically designed for nuclear work, these transducers use a tungsten resistance element. Transducers operate up to 500°F; they have a time response such that in ~0.4 sec the element reaches 63% of final resistance value.—Winsco Instruments and Controls, 11789 W. Pico Blvd., Los Angeles 64, Calif.

Solid-state temperature monitor- and alarm-system for reactor control work operates to temperatures of 1,500°F. The remotely adjustable unit with manual or automatic reset is calibrated at 4 points and has 1% meter indicator with 250 deg rotation and over-all accuracy to 0.5%.—Astra Technical Instrument Corp., 12930 Panama St., Los Angeles 66, Calif.

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LITERATURE AVAILABLE

Solid Film Lubricant Additive. 1 p.; Lord Laboratories, Box 133, Roosevelt Station, Detroit 32, Mich. (samples available).

Tomorrow Metals Today. 12 pp.; Wolverine Tube Division, Calumet & Hecla, Inc., 17200 Southfield Rd., Allen Park, Mich.

Uranium Metal, Intermediate & High Enrichment. UO_2, Low Enrichment Ceramic Grade. 2 pp.; Mallinckrodt Nuclear Division of MCW, 3600 N. 2nd St., St. Louis 7, Missouri.

Aluminum for Nuclear Applications. 25 pp.; AB Svenska Metallverken, Skultuna, Sweden

Four Pi Gas Flow Counter. 2 pp.; Instrument & Development Products Co., Inc., 355 W. 109th Place, Chicago 28, Ill.

Conoseal Union Fitting. 4 pp.; Aeroquip Corp., 11214 Exposition Blvd., Los Angeles 64, Calif.

Straightway Stainless Steel Gate Valve. 4 pp.; Gachot, A.G.B.P. 16, Enghien, France

Centrifugally-Cast Stainless Piping for Nuclear Service. 4 pp.; Sandusky Foundry & Machine Co., Sandusky, Ohio

Centrifugal Casting. 35 pp.; United States Pipe & Foundry Co., Burlington, N. J.

Magnets and Accessories. 12 pp.; Harvey-Wells Nuclear Corp., 43 Kendall St., Farmingham, Mass.

2 Low-Cost, Multi-Purpose Electrometers. 2 pp.;
Megohm Bridge Self-Contained. 4 pp.; Keithley Instruments, 12415 Euclid Ave., Cleveland 6, Ohio

Oscilloscopes and Associated Instrumentation. 16 pp.; Tektronix, Inc., P. O. Box 500, Beaverton, Oregon

Millimicrosecond Oscilloscope, Single or Dual Channel. 6 pp.; Lumatron Electronics, Inc., 116-120 County Courthouse Rd., New Hyde Park, L. I., N. Y.

Electric & Pneumatic Controllers. 56 pp.; Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.

Universal Automatic Check-Out System. 8 pp.; Audiotronics Co., Box 2187, Dayton 29, Ohio

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Vacuum Furnaces. 23 pp.; Consolidated Vacuum Corp., Rochester 3, N. Y.

Nuclear Electronics Laboratory. 8 pp.; Hughes Aircraft Co., Box 90515, International Airport Station, Los Angeles 45, Calif.

Product Catalog. 62 pp.; Radiation Equipment & Accessories Corp., 665 Merrick Rd., Lynbrook, N. Y.

Catalogue No. 3 on Nuclear Equipment. 41 pp.; N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands

Instrument Modernization Service. 2 pp.; Tracerlab, Inc., 1601 Trapelo Rd., Waltham 54, Mass.

New Products for 1961. Burroughs Corp., Electronic Tube Division, Box 1226, Plainfield, N. J.

Elgeet Closed Circuit Television Microscope. 4 pp.; Elgeet Optical Co., Inc., 838 Smith St., Rochester 6, N. Y.

Rare Earth Metals, Revised Data & Costs. 1 p.; Research Chemicals, Box 431, 170 W. Providencia, Burbank, Calif.

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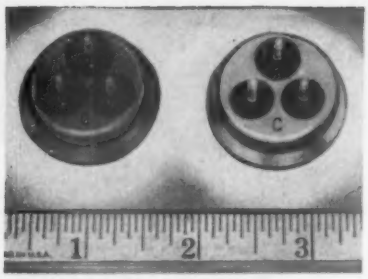

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Products and Materials

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The Army Gas Cooled Reactor Systems Program. 23 pp.; Aerojet-General Nucleonics, P. O. Box 77, San Ramon, Calif.

Nuclear Training Instrumentation. 6 pp.; **Two Transistor Scalers with Pulse Height Analyzer.** 1 p.; **Neutron Generator.** 2 pp.; **Two Transistor High-Speed Scalers.** 2 pp.; Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y.

Isotopic Labeled Compounds. 40 pp.; Nichem Inc., Box 5737, Bethesda 14, Md.

Labeled Compounds for Research. 24 pp.; Volk Radio-Chemical Co., 8260 Elmwood Ave., Skokie, Ill.

Radiochemical & Services Catalog.; Radioactive Chemicals. 28 pp.; New England Nuclear Corp., 575 Albany St., Boston 18, Mass.

Labeled Compounds. 2 pp.; Hazelton-Nuclear Science, 4062 Fabian Way, Palo Alto, Calif.

Controlled Atmosphere Equipment. 2 pp.; Philco Corp., Church Rd., Lansdale, Pa.

Single- or Multi-Station Detection System. 2 pp.; Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

New Products and Literature. 1 p.; **Liquid Scintillation-Counting Systems.** 1 p.; Nuclear-Chicago Corp., 333 E. Howard Ave., Des Plaines, Ill.

Integral-Mounted Photomultiplier Tubes. 1 p.; National Radiac Inc., 475 Washington St., Newark 2, N. J.

Geiger-Mueller Tubes. 1 p.; Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, O.

Automatic Sample-Changing System. 2 pp.; Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass.

Continuous Radioactive Gas & Liquid Analyzers. 6 pp.; Atomic Accessories, Inc., 811 W. Merrick Rd., Valley Stream, N. Y.

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NEWSMAKERS

William C. House will direct Aerojet-General's part in the NERVA (Nuclear Engine for Rocket Vehicle Application) program—a part of the joint AEC-NASA Project Rover. **Charles H. Trent,** manager of the nuclear propulsion div., will assist House who will be responsible for all corporate activities pertaining to NERVA. A special NERVA advisory group of scientists and engineers will assist Aerojet in the execution of the program.

James J. Dickson has been appointed assistant manager of the Allis-Chalmers Nuclear Power Department, Washington. **Joseph V. Cupo** has taken over Dickson's previous position of engineering manager and **Joseph H. Blachly** is the new projects manager.

Alex J. Aronson will head the Nuclear Sales div. of Royal Industries, Inc.'s Vard Division. **Robert A. Almquist** will manage sales at the Aerospace div. of Vard. Both sales divisions have been newly established.

Lloyd B Kramer, formerly manager of development of space electrical power systems at the Westinghouse astronuclear laboratory, has been named manager of nuclear-reactor-core development at the atomic-power department. He will be in charge of research and development for core fuel and control elements. Also at Westinghouse, **M. T. Johnson** has been named operations manager of the Waltz Mill, Pa., testing reactor (WTR). He had previously been associated with naval reactors at the National Reactor Testing Station, Idaho.

United Nuclear Corp., newly formed consolidation of Olin Mathieson's Nuclear Fuels Operation, Nuclear Development Corp. of America, and Mallinckrodt Chemical Works' Commercial Nuclear Operations, has announced the election of three corporate officers: **Alexander Keyes,** secretary; **Edward Savage, Jr.,** general counsel and director of administration; **Robert D. Tegtmeier,** treasurer and controller.

Jay R. Wolff has been appointed vice president in charge of long-range technical planning at Radiation Instrument Development Laboratory, Inc. Wolff, previously technical director at RIDL, will select and evaluate new instrument ideas for possible product development.

Leo Dubinski is the new assistant director for materials for AEC's Compliance div. Dubinski has been with AEC's Oak Ridge National Laboratory for 14 years, most recently as director of the ORNL Compliance div.

Lamar P. Bupp, formerly chemical research and development manager at General Electric's Hanford Laboratories, has been named manager of the GE Vallecitos Atomic Laboratory. **W. Kelly Woods,** temporarily acting manager of Vallecitos, has been appointed programming mgr. at Hanford.

Carroll W. Zabel, formerly a group leader of the physics div. of Los Alamos Scientific Laboratory, has been appointed alternate leader of LASL's reactor-research div. Zabel will be concerned with the development of fission reactors. **Henry T. Motz** assumes the position of physics group leader.

Alfred J. Moses has been named manager, nuclear products department of Hazleton-Nuclear Science Corp. The appointment reflects H-NS's plans for expansion of its activities into the products field which will include, under Moses, a variety of radioactive sources and counting standards, radioactive labeled compounds, and special instrumentation.

Curtiss-Wright Corp.'s Princeton Division has announced the appointment of **John W. Cantwell** as general sales manager and **John J. Baughan** as sales manager for nuclear systems and military products.

Richard L. Doan, manager of the Phillips Petroleum Co. Atomic Energy div., will advise the Turkish Government on nuclear-energy planning. The International Atomic Energy Agency is sponsoring the program of technical assistance to member nations.

J. R. Wolcott has been named manager of the General Electric Atomic Power Equipment Dept.'s nuclear electronic products section with responsibility for design, development, manufacture, and marketing of nuclear electronic systems and components. **Vaughn D. Nixon** will succeed Wolcott as manager of manufacturing, responsible for the production of nuclear reactor components, nuclear fuel and auxiliary equipment.

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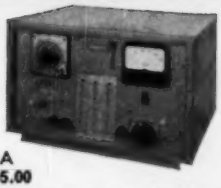

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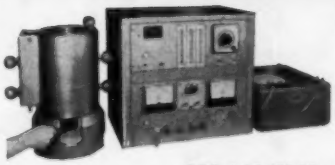

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International Atomic Energy Agency

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September 4–8—Conference on Plasma Physics and Controlled Nuclear Fusion Research, Salzburg, Austria.

August 6–26—Nuclear Physics Summer Course, sponsored by the Italian Physical Society, Varenna, Italy. Contact G. Polvani, Via Saldini 50, Milan, Italy.

August 28–30—Symposium on University Use of Subcritical Assemblies, jointly sponsored by ANS, ORNL, AEC; Gatlinburg, Tenn. Contact Symposium Office, University Relations div., Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn.

September 3–8—140th Meeting of American Chemical Society, including symposium on nuclear technology, Chicago; contact: A. T. Windstead, National Meetings Dept., ACS, 1155 16th St., N.W., Washington 6, D. C.

September 4–9—International Conference on Low-Energy Nuclear Physics, sponsored by International Union of Pure and Applied Physics, Manchester; contact: B. H. Flowers, Manchester U., Manchester 13, Eng.

September 5–12—2nd International Conference on High Energy Accelerators and Instrumentation, sponsored by the Commission on High Energy Physics of the International Union for Pure and Applied Sciences, Brookhaven National Lab., Upton, N. Y. Contact Prof. P. Fleury, Institut d'Optique, 3, Blvd. Pasteur, Paris.

September 6–8—Nuclear Instrumentation Symposium sponsored jointly by ISA, AIEE, IRE; North Carolina State College, Raleigh, N. C. Contact ISA Meetings Manager, Penn Sheraton Hotel, 530 William Penn Place, Pittsburgh 19, Pa.

September 6–9—Meeting of the American Physical Society, Seattle, Wash. Contact W. A. Nierenberg, Univ. of California, Berkeley 4, Calif.

October 8–14—American Rocket Society Annual Mtg., New York; sessions on nuclear propulsion. Contact: R. W. Bussard, Los Alamos Scientific Lab., Box 1663, Los Alamos, N. M.

October 23–26—International Symposium on Aero-Space Nuclear Propulsion, jointly sponsored by AEC, NASA, and the IRE PGNS, including review of SNAP, Rover and Pluto programs, Las Vegas, Nev.; contact: D. J. Niehaus, The Bendix Corp., Detroit, Mich.

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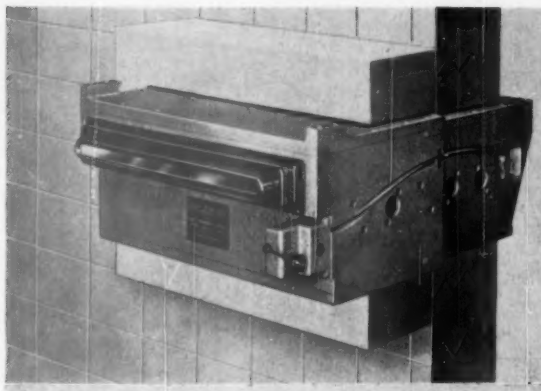

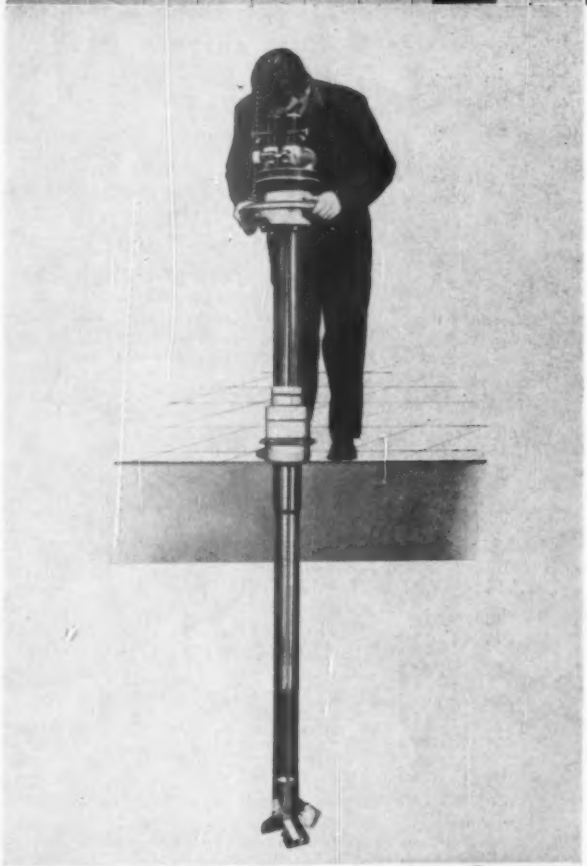

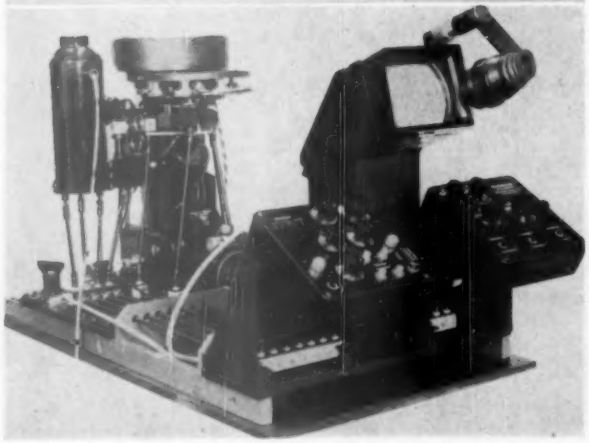

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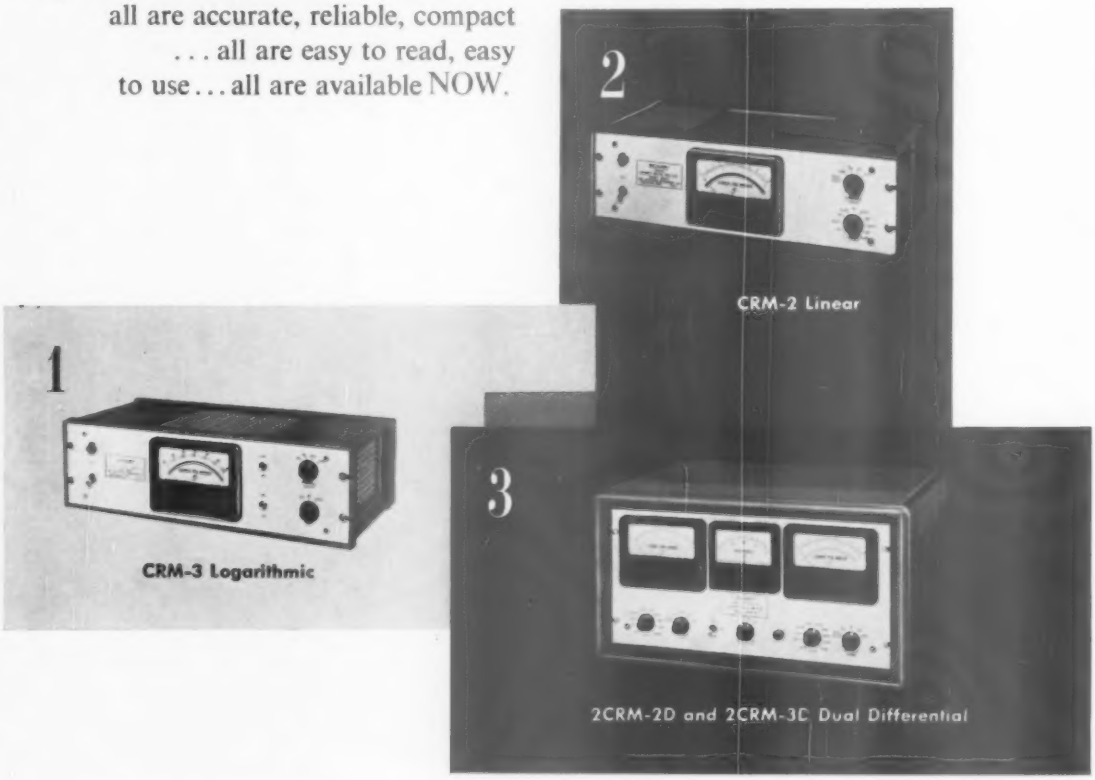

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